CAE Inc.

1135 Innovation Drive
Ottawa, Ont., K2K 3G7 Canada
Tel: 613-247-0342
Fax: 613-271-0963

DRDC CORA TASK #185
COASTAL SURVEILLANCE BASELINE
MODEL DEVELOPMENT

FOR

CSA: **DR. PETER DOBIAS** (250) 363-4830

Team Leader
MARPAC N02 Operational Research
Defence Research and Development Canada
Centre for Operational Research and Analysis
Victoria, B.C.

PWGSC Contract number: W7714-083663/001/SV

27 February 2015

Document No. 5758-001 Version 01

DRDC-RDDC-2015-C028

APPROVAL SHEET

Document No. 5758-001 Version 01

Document Name: DRDC CORA Task #185
Coastal Surveillance Baseline
Model Development

Primary Author

11 Feb 2015
Date

Name **John Brennan**
Position Senior Solution Architect

Reviewer

11 FEB 2015
Date

Name **Scott Guenther**
Position Consulting Services Manager

Approval

11 Feb 2015
Date

Name **Damon Gamble**
Position Project Manager

REVISION HISTORY

Revision	Reason for Change	Origin Date
Version 01	Initial document issued	27 February 2015

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The DRDC CORA Maritime Command Pacific (MARPAC) Operational Research Team has a requirement to develop a baseline intelligence, surveillance and reconnaissance (ISR) model for coastal surveillance. The model needs to be developed in the System Toolkit (STK) software package version 10.0 (or higher) to ensure required fidelity and reliability of the model.

The objective of this activity was to develop an STK model that would incorporate current ISR capabilities employed by the Royal Canadian Navy (RCN) for coastal surveillance, as well as a set of most likely targets. At the high level, creation of this STK model followed sound engineering practices by having design, development and verification phases. A conceptual model was designed, which consists of two implementation-independent views of the problem space; this allowed the conceptual model to be re-used in any potential future related work.

Due to limitations beyond control of the contractor, the model had to be developed in the free version of STK, which is available for public download from the Analytical Graphics Inc. website. This limitation imposed several constraints against the full requirement set established by DRDC, which resulted in a model that was not able to achieve all of the original objectives. Nonetheless, the contractor was able to generate the majority of the platform objects (aircraft, ships, and satellites), as well as provide placeholders for more sophisticated sensor objects once the enhanced version of STK could be acquired.

The procedures used to generate the STK objects and associated routes in the scenario are described in detail. Similarly, the procedures followed and results from surveillance related analysis that was achievable in the free version of STK are provided. The constraints and limitations associated with the free version of STK and with STK in general are itemized as a reference for any follow-on work.

Notwithstanding the constraints and limitations imposed and experienced during the conduct of this work, the contractor was able to achieve measurable successes that will form a firm foundation for any activities that may follow-on from this task in context of the larger DRDC objectives.

1 INTRODUCTION

This document is the Final Report developed for the project entitled “Coastal Surveillance Baseline Model Development”. This report was completed by CAE Canada under Task #185 for contract #W7714-083663/001/SV to Defence Research Development Canada (DRDC) Centre for Operational Research and Analysis (CORA).

1.1 Background

The DRDC CORA Maritime Command Pacific (MARPAC) Operational Research Team has a requirement to develop a baseline intelligence, surveillance and reconnaissance (ISR) model for coastal surveillance. The model needs to be developed in the System Toolkit (STK) software package version 10.0 (or higher) to ensure required fidelity and reliability of the model.

1.2 Objective

The objective of this activity was to develop an STK model that would incorporate current ISR capabilities employed by the Royal Canadian Navy (RCN) for coastal surveillance, as well as a set of most likely targets.

1.3 Scope

Sensors, sensor platforms, and targets needed to be created as STK objects, and implemented in a scenario relevant for the West Coast surveillance tasks (provided in an Annex to the Task statement of work (SOW)). As a minimum:

a) The model needed to capture the full three-dimensional topography of the Canadian East and West Coasts;

b) The platforms and sensors needed to be defined separately. They were to be provided as a library of STK objects that can be re-used in other models, and sensors were to be associated with relevant platforms in the baseline scenario implementation;

c) The model was to incorporate twelve sensor platforms (as a mix of space, air, sea, and ground-based), and relevant sensors as outlined in the SOW Annex;

d) The targets were to be ships as follows: large vessel over 300 gross tonnage (GT) with Automatic Information System (AIS) transmitter, large vessel over 300GT with AIS off, four types of fishing vessels ranging in size between 150ft and 250ft, each with and without AIS transmitter (for a total of eight vessels), four types of small vessels (pleasure craft) ranging in length from 50ft to 100ft, with variable speed (including speed boats) (small/fast, small/slow, large/fast, large/slow); and,

e) The model, including platform and sensor characteristics and disposition, was to be documented in a report.

1.4 Outline

This document contains the following sections:

a) Section 1 – Introduction: a brief description of the background, objective and scope of this work.

b) Section 2 – Design: descriptions of the activities and outcomes associated with the conceptual model and requirements to accomplish the objectives of this work.

c) Section 3 – Implementation: descriptions of the activities and outcomes associated with the development of the STK model required under this work, including limitations and model use of simple analysis.

d) Section 4 – Discussion and Summary: a review and summary of the work done under this task in context of its objectives.

e) Appendix A – Platform Object Route Planning Procedure: a description of the approach and procedure that was used to generate object routes that were implemented in STK.

f) Appendix B – STK Installation & Configuration Instructions: a description of the STK installation and scenario configuration process.

g) Appendix C – Potential Future STK Model Specifications: a listing of the specifications associated with potentially future desirable attributes that could be implemented in the Pro version of STK with custom add-on modules.

h) Appendix D – Sample Access Calculations: details associated with the sample access calculations that were performed on the Task 185 STK scenario developed.

i) Appendix E – Acronyms and Abbreviations: a table containing the acronyms and abbreviations used in this report.

j) Appendix F – References: a list of references made in this report.

2 DESIGN

This section of the report contains descriptions of the activities and outcomes associated with the conceptual model and requirements to accomplish the objectives of this work.

2.1 Conceptual Model

The conceptual model for the context defined in the Task SOW is fairly straight forward. It consists of friendly platforms with sensors conducting surveillance and reconnaissance on surface targets in a coastal maritime environment. This high-level concept, along with some initial details, is depicted in Figure 2-1.

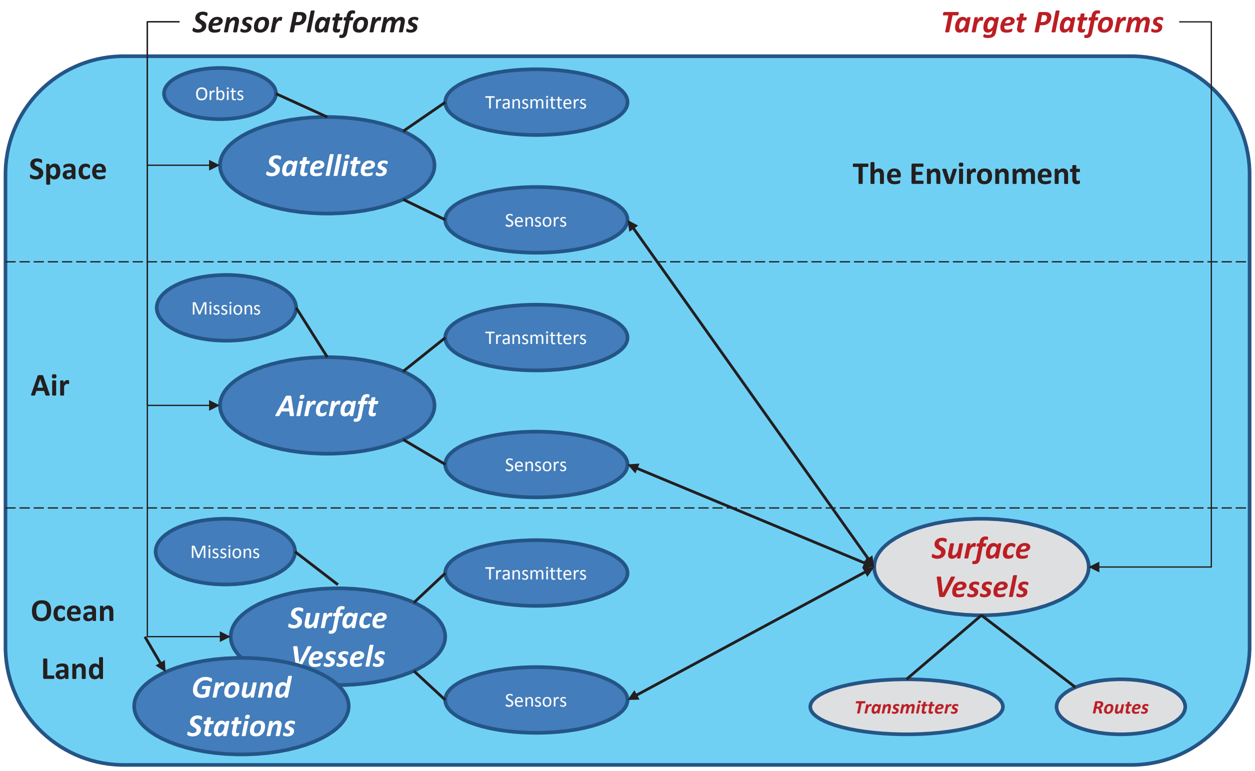


Figure 2-1: Operational Level Conceptual Model

The next level of detail in the conceptual model takes into account some of the specific information provided in the Task SOW regarding the sensor platforms and the target set. The systems level conceptual model is depicted in Figure 2-2.

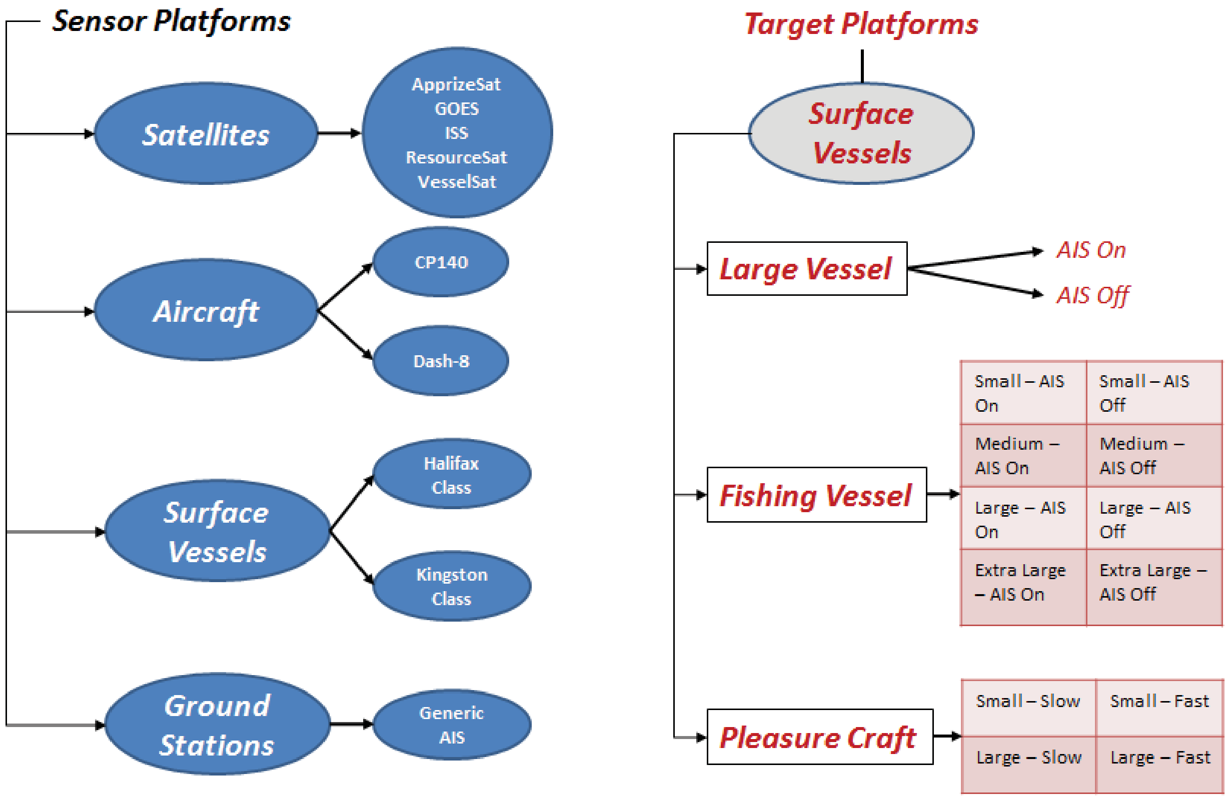


Figure 2-2: System Level Conceptual Model

Having established conceptual views of the problem space, in terms of objects and interactions, one could then set about articulating requirements for the model. The next section of this report identifies the requirements associated with the objectives of this task.

2.2 Requirements

The Task SOW contained statements that one could consider as high-level requirements. Based on these statements in conjunction with review and assessment of the conceptual model in context of the Task objectives, the following table lists the functional requirements.

Table 2-1: Coastal Surveillance Baseline Model Functional Requirements

Requirement Serial	Requirement Statement
RQ-01	The model must capture the full three-dimensional topography of the Canadian East and West Coasts
RQ-02	The model must represent the following platform level objects: satellites, aircraft, surface vessels, and ground facilities
RQ-03	The model must represent the following categories of sensors: radio frequency (RF), electro-optic (EO), infrared (IR), and visual
RQ-04	The model must represent RF-based communication transmitters and receivers
RQ-05	The model must aggregate (attach) sensors, transmitters and receivers onto platforms to represent operational systems
RQ-06	The model must represent typical movement of the platform categories, such as orbits, mission routes, and transit routes
RQ-07	The model must represent a specified time period
RQ-08	The model must contain twelve sensor platforms consisting of a mix of space, air, sea and ground facilities (as per the types identified in Figure 2-2), along with the appropriate sensors as per the Annex to the Task SOW
RQ-09	The model must contain a specified number (as per the Annex to the Task SOW) of target platforms consisting of a mix of the platform types identified in Figure 2-2
RQ-10	The model must be configured to permit calculation of surveillance-relevant metrics, such as time on-station for air-based sensors and revisit period for space-based sensors

3 IMPLEMENTATION

This section contains descriptions of the activities and outcomes associated with the development of the STK model required under this work. It also includes observations that were made regarding constraints and limitations associated with the free version of STK 10.1.3, which was used to conduct this work.

3.1 Model Development

Development of the Coastal Surveillance Baseline Model in STK was done in two main steps:

- Scenario Items; and
- Object Items.

It is important to note that the constraints and limitations imposed by the free version of STK prevented the model development from meeting all of the objectives and requirements. The Annex to the Task SOW identified a variety of platforms and specific or implied sensors that required modelling in context of the higher level objectives associated with this work. Due to the constraints and limitations none of the specific sensors was able to be modelled. In addition, CAE did not obtain any information regarding some of the aspects deemed classified; this was a conscious decision due to the fact that the work was severely constrained by the version of software in use.

Specific constraints and limitations are addressed in the subsequent sections, and a summary of the main issues is captured at the end of this section of the report.

3.1.1 Scenario Items

The Task Technical Authority (TA) identified the time bounds for the scenario model within STK; the start date and end date were set appropriately, at the STK Scenario level, in the model.

The Task SOW indicated the need for the model to capture the full three-dimensional topography of the Canadian East and West Coasts. Subsequent discussions with the Task TA defined the requirement in more detail; the requirement was for all Canadian coastlines on the East and West Coasts, as well as a minimum of 20 nautical miles inland from the coastlines. CAE was able to find the appropriate topographical data to support this requirement; however, it was eventually discovered that the free version of STK does not permit importing terrain data for inclusion in the model.

To help identify the general maritime operating areas associated with Canadian coastal surveillance, CAE used map images that were obtained in the public domain [1]. The West Coast portion of the map is shown in Figure 3-1. This helped guide the placement of area and platform objects and entities within the model.

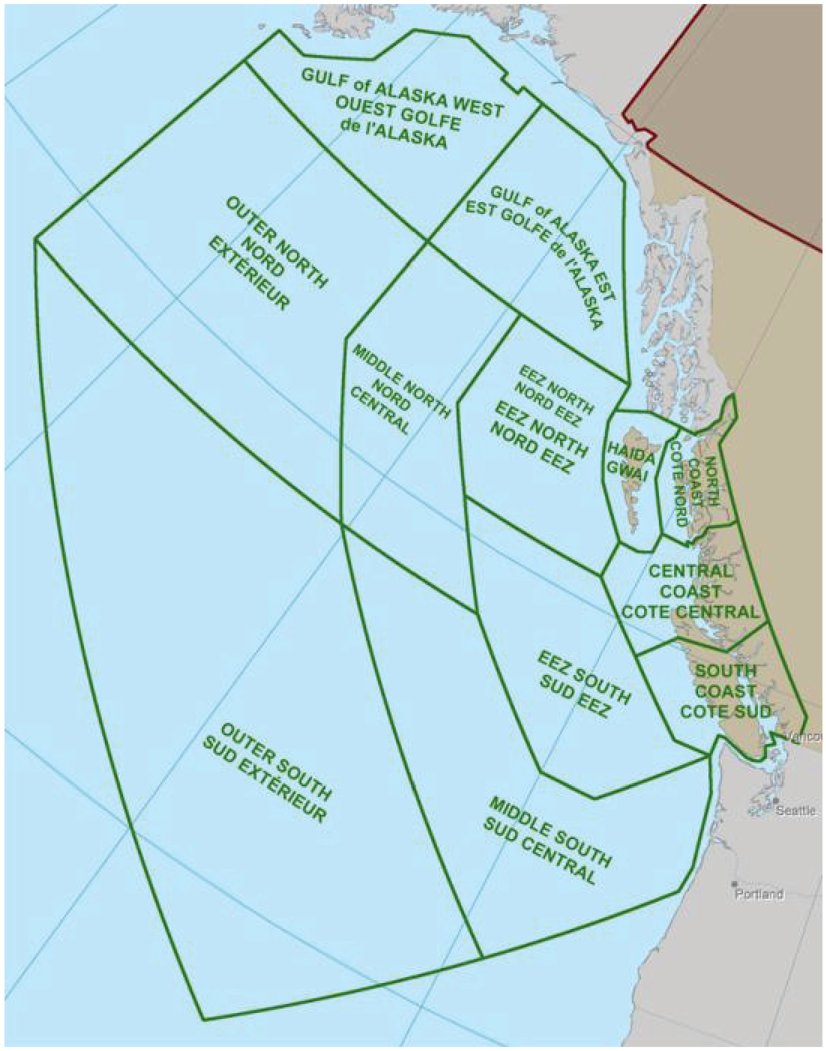


Figure 3-1: West Coast Area of Responsibility[2]

3.1.2 Object Items

The objects in the STK model consist of elements that satisfy the concepts depicted in Figure 2-1 and Figure 2-2, as well as the requirements listed in Table 2-1.

3.1.2.1 Target Platforms

The target platforms for the Coastal Surveillance Baseline Model consist exclusively of surface vessels. Within this group there are three main categories as depicted earlier in Figure 2-2. The Task SOW required the baseline model to contain several hundred targets distributed across the three categories of surface vessels; the standard means for entering ship objects into STK for this many vessels over the 3 month scenario period would have been very time consuming and taken much longer than the time available under this task. Therefore, CAE attempted to create a workflow, supported by an Excel spreadsheet, to generate ship routes in a text file format that can be imported by STK through the ship object's Basic Route properties dialogue. A general description follows while details are contained in Appendix A.

The Excel spreadsheet made use of STK's "Specific Time" Route Calculation Method to link a series of latitude and longitude points together to form a route. The use of the Excel spreadsheet allowed CAE to control the speed and/or time for a given distance. The Specific Time method was also the method that allowed the simplest implementation of objects that needed to appear stationary.

However, even this approach, which did speed the process somewhat, did not provide a means to generate meaningful routes for all targets in the contract time available. The result was that many of the large cargo vessels have the same, overlapping routes, and the majority of pleasure craft are stationary throughout the scenario time period.

Table 3-1 identifies the number of each category of target platform that exist in the STK model as delivered.

Table 3-1: Target Platforms - Number in Model

Vessel Type	Object Name	Sensor Configuration	Number of Type in Model
Large Vessel	Cargo_Vessel_#	AIS On	60
Large Vessel	Cargo_Vessel_#	AIS Off	60
Fishing Vessel Small	Fishing_Vessel_150ft_#	AIS On	15
Fishing Vessel Medium	Fishing_Vessel_175ft_#	AIS On	15
Fishing Vessel Large	Fishing_Vessel_200ft_#	AIS On	15
Fishing Vessel Extra Large	Fishing_Vessel_250ft_#	AIS On	15
Fishing Vessel Small	Fishing_Vessel_150ft_#	AIS Off	15
Fishing Vessel Medium	Fishing_Vessel_175ft_#	AIS Off	15
Fishing Vessel Large	Fishing_Vessel_200ft_#	AIS Off	15
Fishing Vessel Extra Large	Fishing_Vessel_250ft_#	AIS Off	15
Pleasure Craft Small & Slow	Sailboat_Small_#	Not Applicable	15
Pleasure Craft Small & Fast	Motorboat_#	Not Applicable	15
Pleasure Craft Large & Slow	Sailboat_Large_#	Not Applicable	15
Pleasure Craft Large & Fast	Yacht_#	Not Applicable	15

A common sense approach, based on the scenario time of year, was taken regarding distribution of the numbers of each type of target and the geographical location within the model. For example, the pleasure craft are fewer in number and closer to docking locations than if the scenario time-frame had been set during less-stormy months.

The total number of large cargo vessels and smaller fishing vessels were distributed evenly. Both object types represent 40 percent of the target objects while the out of season pleasure craft only represent 20 percent of the object targets.

Further details for each category of target are contained in the subsequent paragraphs.

Large (Cargo) Vessels

The large cargo vessels were created by inserting a default Ship object. This ship object was assigned a Threat Freighter visual model [3] (*threat_freighter.mdl*), which was downloaded from AGI's 3D model repository. No additional changes were made to the basic ship object other than a short description of the vessel.

To assist in generating large vessel routes that aligned closely with real world shipping, CAE used the image in Figure 3-2, which depicts present-day density of commercial shipping.

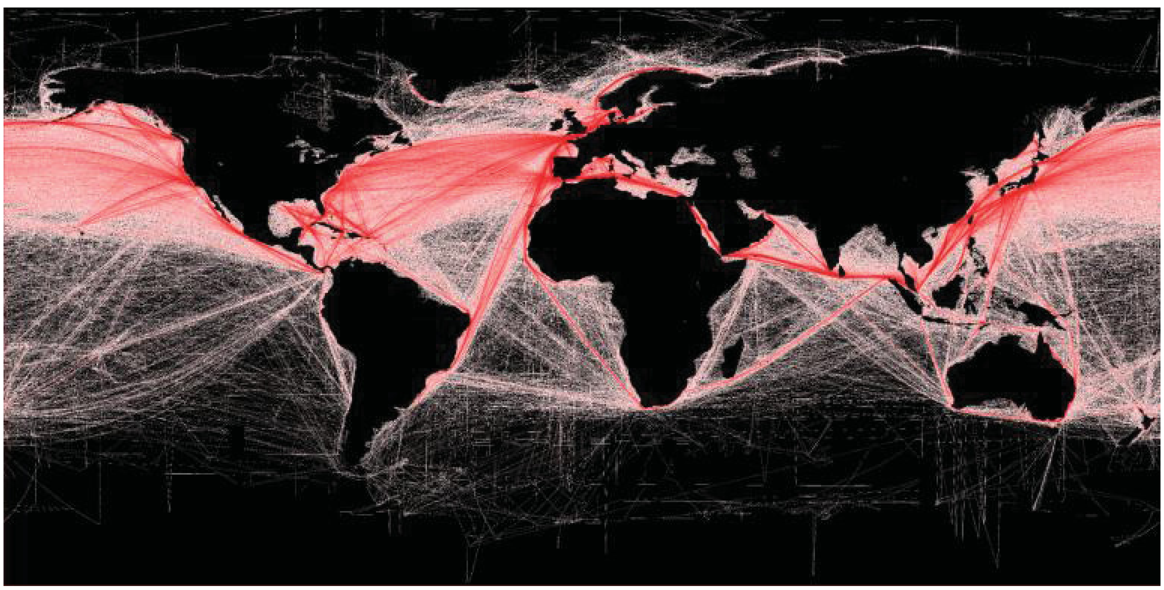


Figure 3-2: Present-Day Commercial Shipping Routes [4]

As per the Task SOW, some of the large vessels were to incorporate AIS sensors. The free version of STK does not permit the creation of Transmitter and Receiver objects. Therefore, the intent to have an AIS sensor was denoted by the presence of a generic Sensor object, which has no specific defining parameters that hold any relevance to a real AIS sensor. The Sensor name is either "AIS_On" or "AIS_Off" to differentiate between targets appropriately as per Figure 2-2.

The large cargo vessels with the "AIS_On" sensor were defined in the scenario as "Cargo_Vessel_1" through "Cargo_Vessel_60". The large cargo vessels with the "AIS_Off" sensor were defined in the scenario as "Cargo_Vessel_61" through "Cargo_Vessel_120".

A variety of shipping routes were generated for the large cargo vessels. Each shipping route was generated by having the vessel travel between two or more of the port cities placed within the STK model. These vessel routes do not necessarily adhere to real world shipping practices or standards. There was insufficient information and time to implement a higher fidelity model.

The Excel spreadsheet method was used by CAE to generate these routes to implement rest times in port and to ensure that no vessel traveled faster than 20 knots, which was arbitrarily selected. Upon arriving in port, a cargo vessel was configured to stay in port for a random amount of time ranging from several hours to several days.

The active port cities in the scenario were selected based on being either commonly known major port cities on the Pacific Ocean or active port cities within the area of responsibility (AOR). In this way, each cargo vessel's time within the AOR was maximized while still attempting to model real-world behaviour as best as possible. Following is a list of the active port cities:

- Anchorage, Alaska, USA;
- Hong Kong, China;
- Honolulu, Hawaii, USA;
- Kitimat, British Columbia, Canada;
- Los Angeles, California, USA;
- Nanaimo, British Columbia, Canada;
- Portland, Oregon, USA;
- Prince Rupert, British Columbia, Canada;
- San Francisco, California, USA;
- Seattle, Washington, USA;
- Tacoma, Washington, USA;
- Vancouver, British Columbia, Canada;
- Victoria, British Columbia, Canada;
- Vladivostok, Russia; and
- Yokohama, Japan.

Originally, 20 different shipping routes were created using predefined routes between ports as a basis for the Excel spreadsheet route planner. These routes were then applied to the first set of cargo vessels having the “AIS_On” sensor (i.e. Cargo_Vessel_1 through Cargo_Vessel_20). These 20 shipping routes where then copied and modified such that their starting ports changed and their routes were reversed. These modified routes where then applied to the first set of cargo vessels which had the “AIS_Off” sensor (i.e. Cargo_Vessel_61 through Cargo_Vessel_80).

These original 40 vessels were then copied to populate the scenario with 60 AIS_On large cargo vessels and 60 AIS_Off large cargo vessels. Unfortunately, there was insufficient contract time available to generate unique routes for all cargo ships. The remaining cargo vessels were each positioned in a random location within the AOR and configured to remain stationary for the duration of the scenario.

Fishing Vessels

The fishing vessels were created by inserting a default Ship object. This ship object was assigned a QST-35 Seaborne Powered Targets (SEPTAR) [5] visual model (*septar.mdl*), which was downloaded from AGI’s 3D model repository. No additional changes were made to the basic ship object other than a short description of the vessel. This generic fishing vessel was then copied and renamed to generate the four different type of fishing vessels based on length: 150ft, 175ft, 200ft and 250ft. Currently, only the object name distinguishes the different fishing vessel types. This is mainly due to the STK limitation of not being able to define an object’s physical dimensions.

As per the Task SOW, some of the fishing vessels were to incorporate AIS sensors. The free version of STK does not permit the creation of Transmitter and Receiver objects. Therefore, the intent to have an AIS sensor was denoted by the presence of a generic Sensor object, which has no specific defining parameters that hold any relevance to a real AIS sensor. The Sensor name is either “AIS_On” or “AIS_Off” to differentiate between targets appropriately as per Figure 2-2. The different types of fishing vessels with the “AIS_On” sensor were defined in the scenario as “Fishing_Vessel__###ft_1” through “Fishing_Vessel__###ft_15”. The large cargo vessels with the “AIS_Off” sensor were defined as “Fishing_Vessel__###ft_16” through “Fishing_Vessel__###ft_30”.

A variety of routes were generated for the different fishing vessels. Each fishing vessel route was generated by having the vessel travel from a home port in the AOR, circle an area in AOR and then return to its home port. These routes do not necessarily adhere to real world fishing patterns, practices or locations. There was insufficient information and time to implement a higher fidelity model.

The Excel spreadsheet method was used by CAE to generate these routes to implement rest times at port and to ensure that no vessel traveled faster than 10 knots, which was arbitrarily selected. The vessel speeds in the Excel spreadsheet were randomized for each leg of a fishing route, and often ranged between 0.5 knots and 9 knots. Upon arriving in port, a fishing vessel was configured to stay in port for a random amount of time ranging from several hours to several days.

Twenty different fishing routes were generated for the scenario. These routes were spread out across nine different port cities within or near the AOR. Table 3-2 identifies the number of fishing routes for each port city.

Table 3-2: Target Platforms – Fishing Route Breakdown

Home Port City	Number of Fishing Routes
Anchorage, Alaska, USA	2
Comox, British Columbia, Canada	3
Kitimat, British Columbia, Canada	2
Nanaimo, British Columbia, Canada	1
Port Hardy, British Columbia, Canada	4
Prince Rupert, British Columbia, Canada	2
Tofino, British Columbia, Canada	3
Vancouver, British Columbia, Canada	1
Victoria, British Columbia, Canada	2

The routes were produced by using the STK 2D Graphics window's Measure function and the CAE Excel spreadsheet. The Measure function was used to quickly generate a set of latitudes and longitudes to layout the route, and the Excel spreadsheet was used to randomize the speed between waypoints as well as the rest times in port.

Pleasure Craft

The four different pleasure craft types were originally created by inserting a default Ship object. The small and slow pleasure craft type was defined as a Small Sailboat, and was assigned a Rubber Boat visual model [6] (rubber_boat.mdl), which was downloaded from AGI's 3D model repository. The small and fast pleasure craft type was defined as a Motorboat, and was also assigned the Rubber Boat model. The large and slow pleasure craft type was defined as a Large Sailboat, and was also assigned the Rubber Boat model. The large and fast pleasure craft type was defined as a Yacht, and was assigned a Cruise Liner visual model [7] (cruiser_liner.mdl), which was downloaded from AGI's 3D model repository.

The pleasure craft objects had no changes made to the basic ship object other than a short description of the vessel. Currently, only the object name and 3D models distinguish between the different pleasure craft types. This is due to the STK limitation of being unable to define an object's physical dimensions.

Unfortunately, there was insufficient time to generate unique routes for the pleasure craft objects. The pleasure craft vessels were positioned in random locations close to the coast within the AOR and configured to remain stationary for the duration of the scenario.

3.1.2.2 Sensor Platforms

Satellite Platforms and Sensors

The STK application comes with access to an unclassified database of satellites and other space-based objects (such as the International Space Station). The parametric data that defines the orbits of these assets (Element Sets) is well-known and relatively fixed due to the nature of orbital operations. Inclusion of the relevant and available satellite platforms in the STK model was relatively straight forward; the appropriate object was identified in the database and then imported into the STK scenario for the relevant time period.

The Task SOW identified RadarSat2 (RS2) as a required space-based asset. The STK satellite database has a pre-defined object for RS2 (Space Surveillance Catalogue (SSC) Number 32382), as well as an apparently full suite of sensors mounted on the satellite. The orbital path of this object was imported into the STK model for the relevant time period

Investigation on the internet in the area of space-based AIS capabilities uncovered information at the following URL: https://icode-mda.googlecode.com/svn/wiki/LessonAIS.wiki. This website contained information identifying specific space-based assets (by name and SSC number) that host AIS sensors. The specific names and numbers are as indicated in Table 3-3.

Table 3-3: AIS Related Satellites

Asset Name	SSC #
AprizeSat-3	35686
AprizeSat-6	37793
GOES-13	29155
GOES-15	36411
ISS	25544
ResourceSat-1	28051
VesselSat-1	37840
VesselSat-2	38047

The space-based asset named ExactView-1 (SSC # 38709) was also found in the STK satellite database; the company exactEarth [8] operates a satellite constellation called exactViewTM that hosts AIS sensors. Therefore, this object and the objects listed in Table 3-3 were imported into the STK model.

Aircraft Platforms and Sensors.

The STK application allows the user to define aircraft objects by specifying a route that consists of a series of waypoints; the route is bounded by a starting location and an ending location. The waypoints in an aircraft route can be established based on time (in which case the speed is calculated) or based on speed (in which case the time is calculated); route waypoints are defined by the following parameters:

- Geographic position (latitude and longitude);
- Altitude;
- Time (in universal coordinated time or UTC) within the scenario; and
- Speed along the route.

Each specific aircraft object is uniquely identified by its object name; the aircraft objects included in the STK model as delivered are identified in Table 3-4.

Table 3-4: Aircraft Objects

Object Name
CP140_Aurora
PAL_Dash-8
Generic_Sensor

In the real world, the CP140 assets are located at 19 Wing at Canadian Forces Base (CFB) Comox on Vancouver Island. In the STK model, the CP140 object has its origin at this location and it was assigned two arbitrary (unclassified) routes within the west coast AOR during the time period of the scenario. The CP140 object travels these routes at an altitude of 20,000ft and a speed of 320 knots for no more than a period of 10 hours. The CP140 travels one of the two routes on average twice each week at random times. These routes and the randomized times were generate using the CAE Excel spreadsheet.

The CP140 object was created by adding a Lockheed P-3C_Orion profile from the STK 10 aircraft database. The P-3C_Orion profile was renamed to CP140_Aurora. No additional changes to the object were made due to the STK limitation of being unable to define an object's dimensions.

The CP140 was then provided with six different unclassified, generic sensor objects. These sensor objects included an AIS placeholder object, an EO/IR sensor object, a basic pilot/crew Visual sensor object and three different Radar objects to model the field of regard for the radar on the CP140.

Given the limitations of the free version of STK the model development for the CP140 radar sensor required two components:

- Definition and assignment of three separate generic sensors to provide visual representation of the radar field of regard (similar to the depiction in Figure 3-3); and

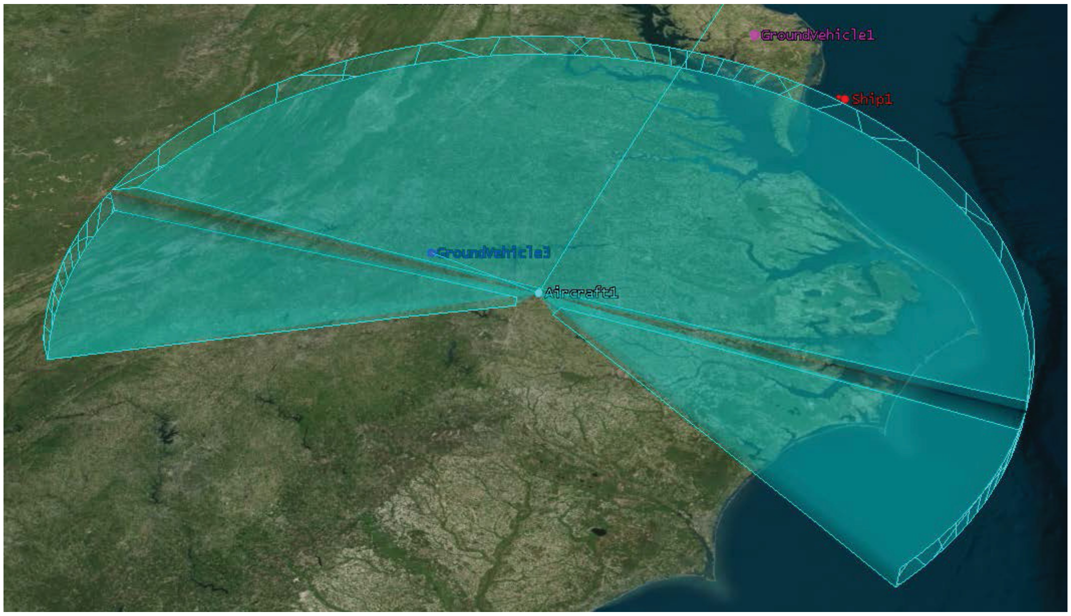


Figure 3-3: Generic Sensor Visualization

- Definition of aircraft-object-level Constraints in the Basic Properties window (Figure 3-4) as a simplistic approach to modelling the radar sensor envelope to enable straight forward, line-of-sight Access calculations against targets in the model.

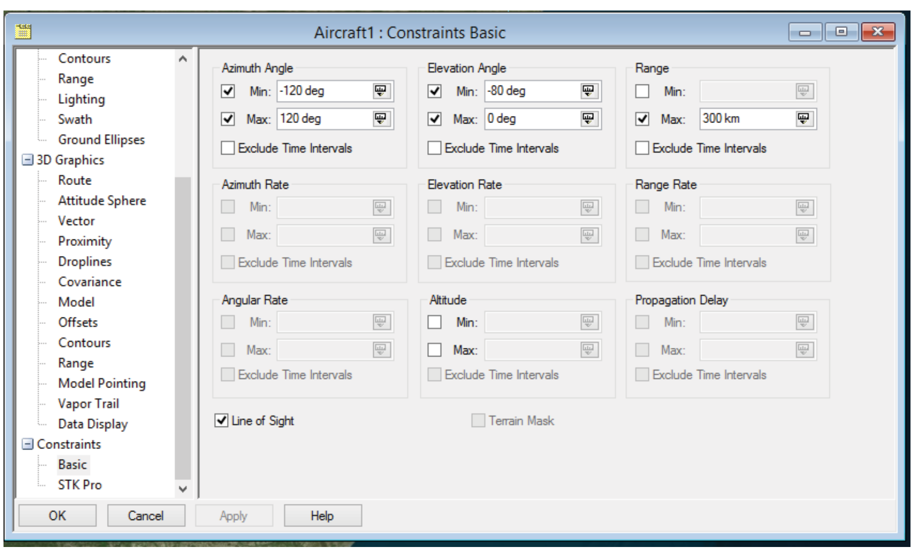


Figure 3-4: Basic Constraints for Access Calculations

The parameters used to define the CP140 generic sensor objects in the STK model are identified in Table 3-5.

Table 3-5: CP140 Generic Sensor Definition Parameters

Object Name	Sensor Type	Cone Half Angle (deg)	Vertical Half Angle (deg)	Horizontal Half Angle (deg)	Pointing Azimuth (deg)	Pointing Elevation (deg)	Azimuth Angle Min (deg)	Azimuth Angle Max (deg)	Elevation Angle Min (deg)	Elevation Angle Max (deg)	Range Max (km)
CP140_EO_IR	Simple Conic	90			0	90					50
CP140_Radar_Left_Arc	Rectangular		15	15	-150	15	-120	120	-80	0	300
CP140_Radar_Main_Arc	Rectangular		90	15	0	15	-120	120	-80	0	300
CP140_Radar_Left_Arc	Rectangular		15	15	150	15	-120	120	-80	0	300
CP140_Visual	Simple Conic	90			0	90					10

In the STK model, the PAL_Dash-8 object has its origin at Comox [9] and it was assigned two arbitrary (unclassified) routes along the west coast AOR during the time period of the scenario. The PAL_Dash-8 object travels these routes at an altitude of 22,500ft [10] and a speed of 290 knots [11] for no more than a period of 6 hours. The PAL_Dash-8 travels one of the two routes approximately once each week at random times. These routes and the randomized times were generated using the CAE Excel spreadsheet.

The PAL_Dash-8 object was created by inserting a default Aircraft object. This aircraft object was assigned a Beechcraft 1900 Commuter [12] model (*commuter.mdl*), which was downloaded from AGI's 3D model repository. No additional changes were made to the basic aircraft object other than a short description of the aircraft.

The PAL_Dash-8 was then provided with four (4) different unclassified sensor objects. These sensor objects include an AIS placeholder object, an IR sensor object, a basic pilot/crew Visual sensor object and a Radar sensor object. These sensors were built using basic unclassified information from the Canadian Department of Fisheries and Oceans [13].

The parameters used to define the PAL_Dash-8 generic sensor objects in the STK model are identified in Table 3-6.

Table 3-6 PAL Dash-8 Generic Sensor Definition Parameters

Object Name	Sensor Type	Cone Half Angle (deg)	Pointing Azimuth (deg)	Pointing Elevation (deg)	Range Max (km)
PAL_FLIR	Simple Conic	90	0	90	50
PAL_Search_Radar	Simple Conic	90	0	90	320
PAL_Visual	Simple Conic	90	0	90	10

In the STK model, a generic Aircraft object was created to represent the behaviour of an "*all-seeing*" sensor; this was done at the request of the task TA. This object was placed at an altitude of 200 km over the AOR and configured to remain stationary for the duration of the scenario period. The aircraft object was provided with a "Generic_Sensor" sensor object to model the desired behaviour.

Surface Vessel Platforms and Sensors

The STK application allows the user to define Ship objects in a similar fashion as for Aircraft objects with the key difference being that there is no altitude parameter.

The Halifax_Class object was created using information obtained in the public domain. It was created by inserting a default Ship object in the scenario. This Ship object was assigned a Type 23 Frigate [14] visual model (type_23_frigate.mdl), which was downloaded from AGI's 3D model repository. No additional changes were made to the basic ship object other than a short description of the vessel.

The Halifax_Class was provided with four (4) different generic sensor objects. These sensor objects include an AIS placeholder object, an IR sensor object, a basic crew Visual sensor object and a Radar sensor object. These sensors were defined using basic unclassified information from several different sources [15] [16] [17].

Table 3-7: Halifax_Class Generic Sensor Definition Parameters

Object Name	Sensor Type	Cone Half Angle (deg)	Pointing Azimuth (deg)	Pointing Elevation (deg)	Range Max (km)
Halifax_AN_SPS_505	Simple Conic	90	0	90	88
Halifax_IR	Simple Conic	90	0	90	10
Halifax_Visual	Simple Conic	90	0	90	10

In the STK model, the Halifax_Class object uses CFB Esquimalt as its home port. The Halifax_Class object repeats a single arbitrary route within the west coast AOR during the time period of the scenario. It travels this route at a speed of 10 knots for a period of approximately 26 days then returns to port for a randomized rest period of between four (4) and seven (7) days. These routes and the randomized times were generated using the CAE Excel spreadsheet.

The Kingston_Class object was created using information obtained in the public domain similar to the Halifax_Class object. The Kingston_Class object was assigned an Offshore Patrol Cutter (OPC) [18] visual model (opc.mdl), which was downloaded from AGI's 3D model repository. No additional changes were made to the basic ship object other than a short description of the vessel.

The Kingston_Class was provided with three (3) different generic sensor objects. These sensor objects include an AIS placeholder object, a Radar sensor object, and a basic crew Visual sensor object. These sensors were built using basic unclassified information from several different sources [19] [20] [21].

Table 3-8: Kingston_Class Generic Sensor Definition Parameters

Object Name	Sensor Type	Cone Half Angle (deg)	Pointing Azimuth (deg)	Pointing Elevation (deg)	Range Max (km)
Kingston_Radar	Simple Conic	90	0	90	44
Kingston_Visual	Simple Conic	90	0	90	10

In the STK model, the Kingston_Class object uses CFB Esquimalt as its home port. The Kingston_Class object repeats a single arbitrary route along the west coast of the AOR during the time period of the scenario. It travels this route at a speed of 8 knots for a period of approximately 13 days then returns to port for a randomized rest period of between three (3) and five (5) days. These routes and the randomized times were generate using the CAE Excel spreadsheet.

<u>Ground Stations</u>

A single generic STK Facility called AIS_Ground_Station was added to the scenario, and placed in the CFB Comox area. A place holder “AIS_Rx” sensor was attached to the facility. No additional work was done to model this object due the lack of the STK Communications Module and the detailed specifications concerning capability and placement of such a facility.

A generic STK Facility was also added to the scenario, and placed in the CFB Esquimalt area.

3.1.2.3 Area Target Objects

STK allows users to instantiate and define objects to represent geographic areas on the surface of the earth; these are known as Area Target Objects. STK comes with a set of pre-defined Area Target Objects based primarily on political boundaries; users are also able to define custom areas through free-form specification of bounding points.

In the current STK model, a set of areas was defined for two reasons:

- To provide visual assistance during ship and aircraft route planning; and
- To support the execution of sample Access calculations.

The second reason will become more important to future work if the STK Coverage module is obtained; this will facilitate the execution of detailed coverage analyses, for which Area Target Objects are required when defining the coverage areas.

The areas added to the current STK model were:

- An approximation of the MARPAC region, using 13 Area Target Objects, based on public domain data [22] (as per Figure 3-1) depicted in Figure 3-5 below;
- The main body of the STK pre-defined Canadian region;
- The STK pre-defined continental United States; and
- The STK pre-defined Alaska area.

The Canadian, United States and Alaska regions were imported through STK's "Select Countries and US States" area target creation method. The MARPAC regions were implemented manually through rough estimations of appropriate latitudes and longitudes.

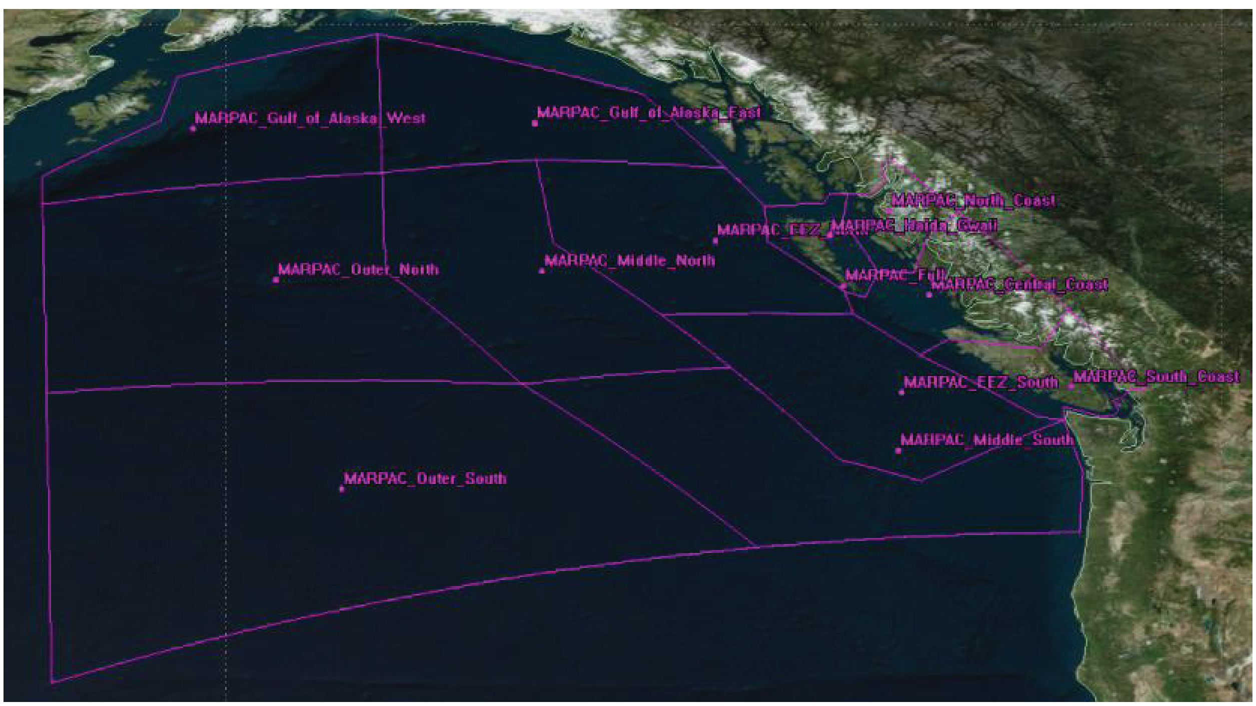


Figure 3-5: MARPAC Region Area Target Objects

3.1.2.4 Places

STK allows users to instantiate and define objects to represent specific geographic locations on the surface of the earth; these are known as Place Objects. STK comes with a set of pre-defined Place Objects based primarily on cities; users are also able to define custom places through free-form specification of points.

In the current STK model, a large number of places were added to the scenario to facilitate planning and analysis. The places added to the scenario include:

- Major cities within the AOR;
- A set of Canadian Forces Bases;
- Notable checkpoints for the design of shipping routes; and
- Major port cities on the Pacific Ocean [23].

The Place Objects where added via the STK City Database or as a generic place, which was provided with an appropriate latitude and longitude acquired from Wikipedia.

3.2 Model Limitations

Following is a list of limitations associated with the free version of STK.

- One cannot directly import terrain data such as Digital Terrain Elevation Data (DTED) and Digital Elevation Maps (DEMs); one needs the STK Pro version to enable this feature.
- For sensors, one is limited to defining simple conic and rectangular sensors with no ability to identify or define operating parameters related to the spectrum within which the sensor operates (e.g. RF, IR). Furthermore, the simple sensor is fixed in azimuth and elevation (a “staring” sensor) meaning it cannot be set-up to scan in any fashion. Implementation of specific RF sensors requires purchase of the STK Radar add-on module.
- One cannot define communication related systems (transmitters and receivers), and hence there was no ability to define AIS objects in the current version of the model.
- One cannot perform coverage analyses; for this one needs to purchase the STK Coverage add-on module, which then facilitates the definition of area targets and figures of merit to support coverage calculations.

Following is a list of observations associated with STK in general.

- In general, there is no manner in which one can explicitly define an object’s physical size or mass. If one were to purchase the STK SatPro or Astrogator add-on modules, then one obtains access to the Mass option for satellite objects; in addition through use of the STK

Aircraft Mission Modeler add-on module one can configure aircraft fuel tank weights. However, these discrete add-on options do not apply to objects in general.

- There is no means to “bulk copy / assign” a sensor (or similar) object to existing platform objects (aircraft, satellites, ships). In the case where one defines a sensor or communications object (such as an AIS transmitter) that will exist on several different platforms, one must assign (using a copy and paste function) the object to each platform individually. Using this approach, STK assigns each “pasted” sensor a unique name by sequentially incrementing an appended integer. One can then amend the assigned names so that all sensors that are of the same configuration have the same name. In this case, one must be aware that any changes made to any of the sensors with that name, when saved (at the sensor level) will then apply to all sensors holding that name.

3.3 Model Use – Analysis

The higher level objective of the MARPAC Operational Research Team, which this task is intended to support in part, is research and analysis associated with coastal surveillance. The Task SOW indicated a need to report on characteristics relevant to the domain of coastal surveillance that can be addressed by a tool such as STK; these include items such as time on station for an air-based sensor and revisit period for a space-based sensor. Although STK is highly suitable for this type of analysis, based on its advanced geometry engine and system modelling, the free version of STK limits the type of analytical calculations that can be performed. Nonetheless, CAE configured and ran some of the basic Access calculations that are possible in the free version of the tool; descriptions of the computations performed are in the following sections, while details associated with the output are contained in Appendix D.

Under constraints of tool functional limitations and time available, CAE was able to run Access calculations in two general categories: Geographic-Based Access and Target-Based Access.

3.3.1 Geographic-Based Access

Simple Geographic-Based Access calculations involve analysis as to when a platform object (aircraft, satellite, ship) is within line of site of a point or area on the surface of the earth. In the available version of STK one is able to invoke these simple, geometry-based calculations, which can also take into account any Basic Constraints that may have been defined for a particular object (such as those defined for the CP140 Aircraft object depicted in Figure 3-4). Since detailed terrain and feature data cannot be imported into the free version of STK, terrain masking limitations cannot be taken into account; the only earth-based constraint that is accounted for is the curvature of the earth based on the inherent earth ellipsoid model inherent to STK (selected as WGS-84).

To perform Geographic-Based Access calculations, one must first define an appropriate geographical area (as STK Area Target Objects) against which Access calculations can then be run[1]. This was done as per the description in Section 3.1.2.3. The next step is to identify the platform objects of interest for the Access calculations. For the purposes of this task, the aircraft and satellite platform objects were used. Examples on the configuration of and results from these Access calculations are contained in Appendix D.

3.3.2 Target-Based Access

Simple Target-Based Access calculations involve analysis as to when a platform object (aircraft, satellite, ship) is within line of site of one or more other platform objects. In the available version of STK one is able to invoke these simple, geometry-based calculations, which can also take into account any Basic Constraints that may have been defined for a particular object. Since detailed terrain and feature data cannot be imported into the free version of STK, terrain masking limitations cannot be taken into account; the only earth-based constraint that is accounted for is the curvature of the earth based on the inherent earth ellipsoid model inherent to STK (selected as WGS-84).

STK is capable of calculating when sensors are able to see (detect) specified targets based on geometry, as well as sensor and target characteristics; the computations can also take into consideration a variety of environmental factors if desired. However, these more sophisticated analyses require STK Pro and a series of add-on modules (such as Communications, Radar and Coverage) that must be purchased.

With the tool available, CAE conducted some investigations and experimented with some simplistic calculations. The first calculations were run using the CP140 Aircraft Object against the full set of Cargo Vessel Objects for the duration of the scenario; the result produced a very large number of Accesses that were considered too numerous for inclusion in this report. Therefore, the Access was reconfigured to cover only the first two weeks of scenario time and only the first 10 Cargo Vessel Objects. The results were more manageable but this activity demonstrated that unless the analyst is interested in a specific target of interest, object-to-object analysis may not be the most suitable in STK. Given the author's past experience with STK, as well as videos viewed through the AGI website, it is likely of better use for the model to be configured to perform area coverage calculations, which require the STK Coverage module. Some details on this module are contained in Appendix C.

Attempts were made to conduct Ship Object-based Access calculations; however, problems were encountered with the model as originally configured in that "No Access Found" results were generated. It was believed that this was due to the manner in which STK represents and places Ship Objects on the STK Globe. AGI Technical Support was contacted to determine the source of the issue and to see if there was a means to allow access calculations to be done for Ship Objects. AGI Technical Support confirmed that within STK default Ship Objects cannot see one another due to the curvature of the earth because Ship Objects are placed as point objects directly on the surface of the earth. However, in the Basic Constraints properties of the Ship Object, one can deactivate the Line of Sight constraint, which essentially "removes the earth" as a line of sight barrier to Access calculations. AGI Technical Support recommended

[1] Note that STK Pro along with the STK Coverage module provides the ability to conduct finer coverage calculations based on grid patterns, defined figures of merit and specific sensor assignments; however, this was not possible under this task. Further details are contained in Appendix C.

this approach coupled with specification of a small negative value minimum elevation angle constraint could be used as a means to allow Access calculations to “look down” from the Ship Object’s perspective (Figure 3-6) [24]. In addition, any other Ship Objects within the STK scenario that will be used as targets for Access calculations must also have the Line of Sight option deselected in Basic Constraints; however, there is no need to set a minimum elevation for these objects. This work-around was implemented in the STK model as a last minute change; Access calculations were quickly tested and proved to be successful.

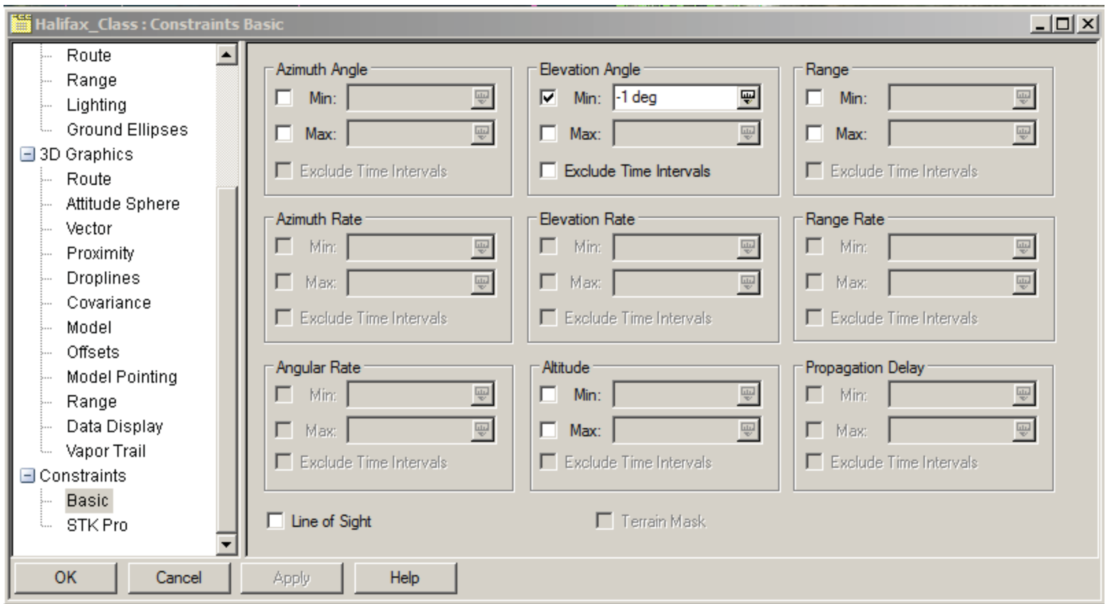


Figure 3-6: Ship Object Basic Constraints for Access Calculations

4 DISCUSSION AND SUMMARY

This section of the report contains a review and summary of the work done under this task in context of its objectives.

The top-level objective of this work was presented clearly through the Task SOW and discussions with the task TA during the kick off meeting and subsequent exchanges during course of the work. It was identified early on that there were going to be limitations in what could be achieved due to constraints imposed by the free version of STK. Notwithstanding this, the early conceptual phases of the work were approached from an implementation independent perspective in the mindset that more sophisticated versions of the STK platform may be available in the future. As such, the conceptual models produced will prove reusable if follow-on work is conducted.

Model implementation proceeded with the main focus on creating baseline object profiles that could be enhanced in the future. From a target platform perspective, all required objects (300 targets consisting of a mix of types) were generated as best as possible in the current model. From a sensor platform perspective a different approach was taken, the main reason being that these platforms were intended to host more sophisticated sensor objects and creation of multiple simplified objects would only increase the amount of re-work required in the future. Therefore, the current model contains only a single instance of each of the aircraft and ship sensor platforms, with generic sensor child-objects as placeholders for the more sophisticated sensor objects if enhanced versions of STK are acquired in the future. The satellite objects identified earlier in the report were imported as-is from the existing STK Satellite Object Database and propagated for the duration of the scenario period.

In creating the target platforms, it was observed that STK is not necessarily well-suited for generating object routes for long periods of time (such as weeks and months) other than orbital objects for which the built-in orbital propagator accomplishes this task. The use of the Aircraft Mission Modeler may ease this activity for Aircraft Objects; however, CAE was not able to explore this option because it is not available in the free version. Nonetheless, this would not address the challenges associated with Ship or Ground based objects.

STK also did not seem well-suited for organizing large numbers of objects over long periods of time. There is no apparent method for grouping categories of objects in a hierarchical or other fashion; all scenario objects are placed at the same level within the scenario, which can make navigating the objects challenging and cumbersome in the STK Object Browser when the number of objects is large. Although it was not available in the free version of STK, CAE is aware that there is a Constellation Object that can be used; the STK Help files provide indication that Constellation groups can be created using any object types but CAE was not able to verify or experiment with this option. There is potential that Constellation Objects might make object management for analysis somewhat easier. This should be investigated if an enhanced version of STK is acquired.

In Section 2.2 of this report the set of functional requirements derived for this work were listed in Table 2-1. This section of the report provides an overview assessment of whether or not these requirements were met. This information is contained in Table 4-1 below.

Table 4-1: Requirements Verification Status

Requirement Serial	Requirement Statement	Requirement Status
RQ-01	The model must capture the full three-dimensional topography of the Canadian East and West Coasts	**Not Met** The free version of STK is unable to import terrain data
RQ-02	The model must represent the following platform level objects: satellites, aircraft, surface vessels, and ground facilities	**Met** The model represents the types of objects specified
RQ-03	The model must represent the following categories of sensors: radio frequency (RF), electro-optic (EO), infrared (IR), and visual	**Partially Met** The free version of STK can only generate simple generic sensors
RQ-04	The model must represent RF-based communication transmitters and receivers	**Not Met** The free version of STK is unable to represent transmitters and receivers
RQ-05	The model must aggregate (attach) sensors, transmitters and receivers onto platforms to represent operational systems	**Partially Met** The model has generic sensors attached where suitable but does not represent operational systems
RQ-06	The model must represent typical movement of the platform categories such as orbits, mission routes, and transit routes	**Met** The model incorporates orbits (satellites), mission routes (sensor platforms) and transit routes (targets)
RQ-07	The model must represent a specified time period	**Met** The model covers the time period specified in the Task SOW
RQ-08	The model must contain twelve sensor platforms consisting of a mix of space, air, sea and ground facilities (as per the types identified in Figure 2-2), along with the appropriate sensors as per the Annex to the Task SOW	**Partially Met** The model contains 15 sensor platforms consisting of a mix but it does not contain properly modelled sensors due to limitations of the free version of STK
RQ-09	The model must contain a specified number (as per the Annex to the Task SOW) of target platforms consisting of a mix of the platform types identified in Figure 2-2	**Met** The model contains the requisite number of target platforms, several of which have suitable routes assigned to them.
RQ-10	The model must be configured to permit calculation of surveillance-relevant metrics such as time on-station for air-based sensors and revisit period for space-based sensors	**Partially Met** The free version of STK has limited analytic capability. Simple access calculations were performed where able

STK did “crash” several times on the development platform that was being used. The author is aware from past experience with STK that the application can be demanding on the host platform from a couple of different perspectives. If the scenario has many sophisticated visualization aspects such as high resolution terrain and imagery, as well as sophisticated sensor representations being visualized, then the host platform would require an equally sophisticated graphics processing capability. This was not the case for the work conducted under this task since terrain data could not be imported, nor could any sophisticated sensors be modelled. The other aspect that could place a high processing demand is scenario complexity from the perspectives of number of objects and scenario duration. The STK hardware requirements and the specifications of the develop platform used during this work are provided below.

Table 4-2: STK Hardware Recommended Requirements [25]

Hardware	Requirement
CPU Speed	2+ GHz
Processor	Intel Core Duo, SSE2 (or greater) Pentium 4 or Xeon Processors
Memory / RAM	3+ GB
Disk Space	2+ GB
Video Card	High-end OpenGL-compatible card (512+ MB memory) that supports OpenGL 2.0+. To determine whether the graphics card installed on your system is supported by STK, from the Start->All Programs Menu, select STK Support Tools->Graphics Card Information. Note: Integrated motherboard chipsets, such as Intel Integrated Graphics, should be avoided.
Network Hardware	Network Card Required

Table 4-3: Task #185 Development Platform Specifications

Hardware	Specification
CPU Speed	3.20 GHz
Processor	Intel Core i5-4570
Memory / RAM	8 GB (3.43 GB usable)
Disk Space	465 GB
Video Card	Intel HD Graphics 4600
Network Hardware	Intel Ethernet Connection I217-LM

Instructions on how to install the free version of STK as well as the Task 185 scenario delivered through this work are provided in Appendix B.

APPENDIX A PLATFORM OBJECT ROUTE PLANNING PROCEDURE

This appendix contains a description of the procedure that was used by CAE for planning and implementing routes for Ship and Aircraft Objects within the STK model.

A procedure to generate STK Specific Time routes was conceived, created and adopted to quickly produce large numbers of recurring routes. Some of the routes generated for the three-month period within the scenario contain between 80 and 1,500 different waypoints. CAE recommends that the standard route generation procedure within STK tool be used when generating a small number of waypoints.

The following procedure is a record of what was done to generate the STK Specific Time routes. CAE does not imply that this method is the best or most effective way to generate long-term paths for multiple objects in STK; however, it was found to be useful for the work required by this task.

The first part of the process is to generate a set of points on the map, which will define the desired route for the object. Each point needs to include latitude and longitude value measured in degrees. One of the quickest ways of generating this set of points is to use the Measure button in STK's 2D Graphics window (Figure A-1).

The Measure button can be used to measure the distance between any two points. This is done by clicking the Measure button in the 2D Graphics window, and then clicking and dragging the mouse between the two points on the 2D Graphics window you want to measure. The latitude and longitude of the two points, the shortest distance between the two points and the azimuth bearing will be displayed in the Status Bar and the Message Viewer once the mouse button is released.

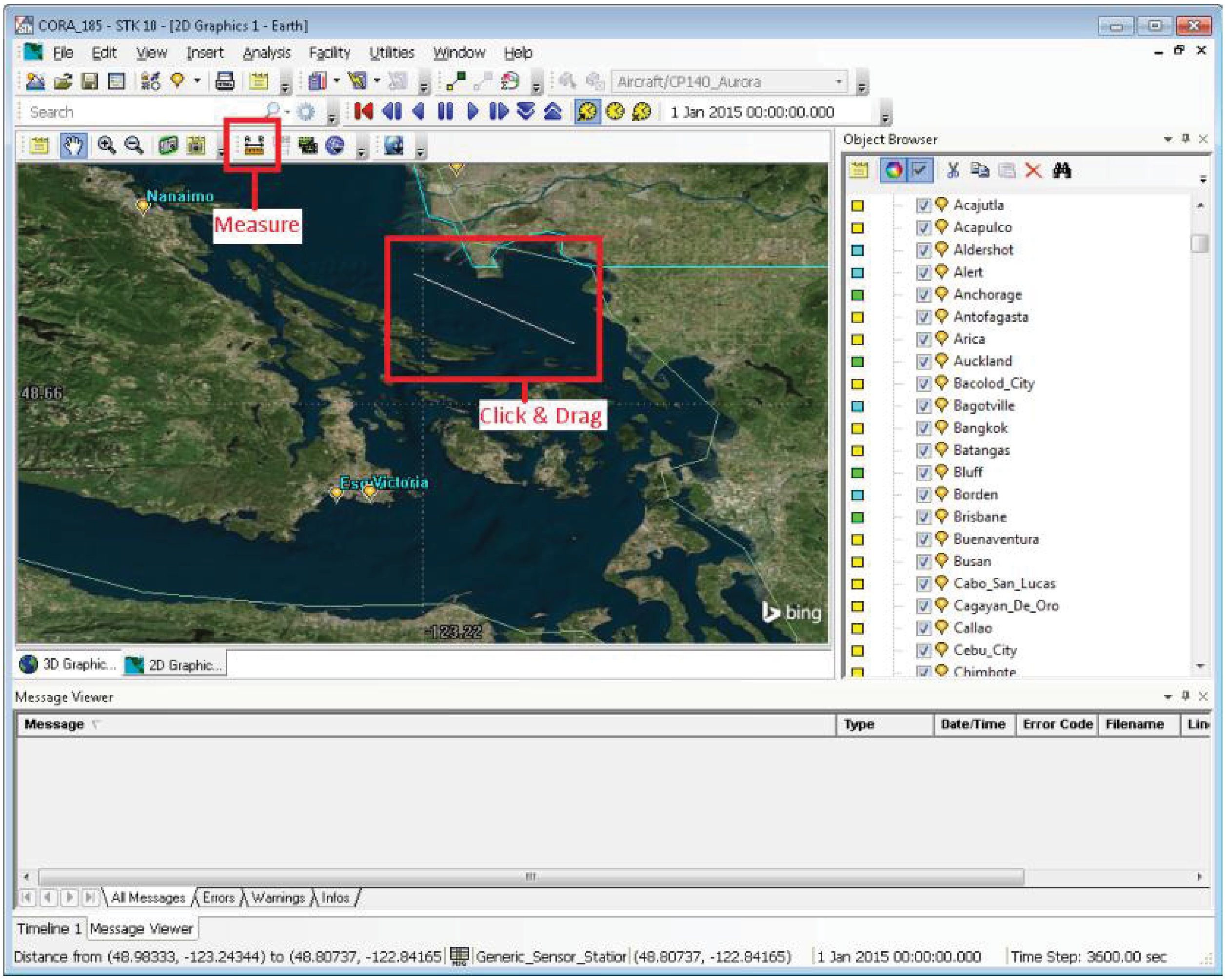


Figure A-1: STK Measure Function in the 2D Graphics Window

Repeating this process across the desired route will generate the necessary set of points for the route definition in degrees within the STK Message Viewer.

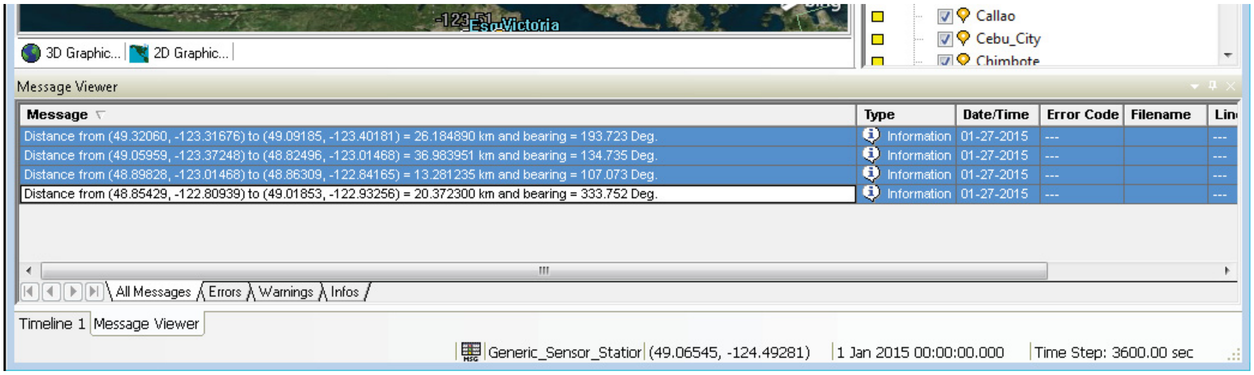


Figure A-2: Multi-selection of Measure messages in the STK Message Viewer

Select all the distance info messages by clicking on the first message, holding down the SHIFT key, and then select the last message (Figure A-2). Copy the selection by pressing CTRL+C and paste the distance messages into a text editor (Figure A-3).

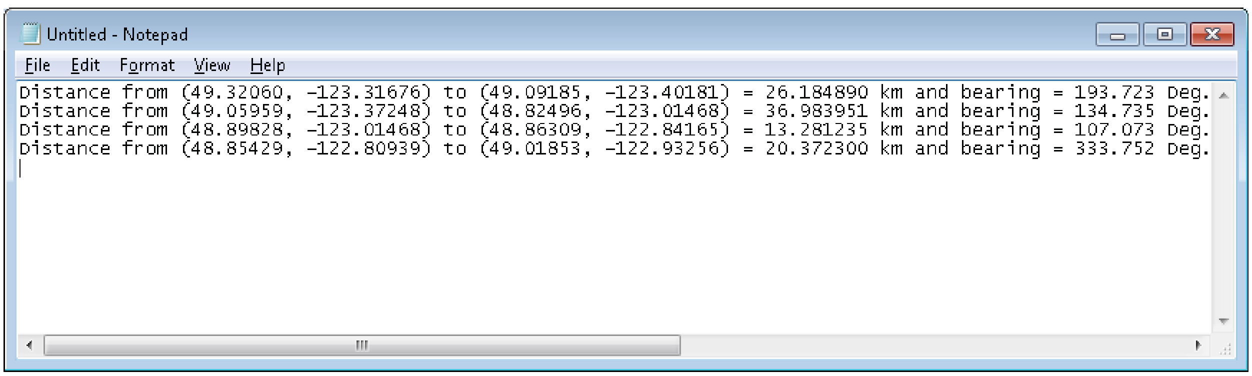


Figure A-3: Pasting the STK Measure Messages into a Text Editor

The text editor can then be used to remove the excess information so that only the latitude and longitude information remains. Each point must be placed on its own line within the text editor, where the latitude and longitude value are separated by a single TAB (Figure A-4).

This can be completed very quickly for a large number of points by either writing an appropriate script or using free open source software. For example, the regular expression option in Notepad++'s Replace All functionality was used during this project to convert hundreds of points into the desired format in only a few button presses.

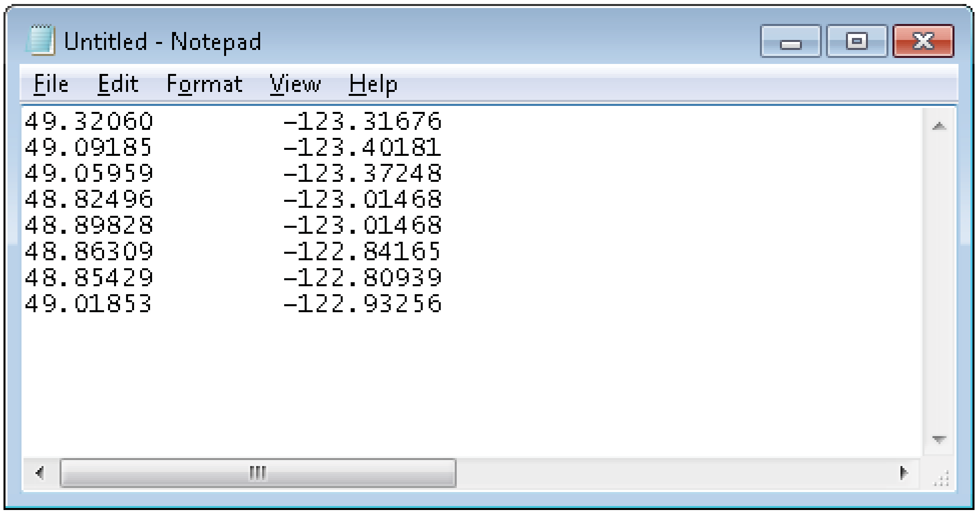


Figure A-4: Formatting the STK Measure Messages into Usable Data for the “Route Planning Template” Excel Spreadsheet

Once properly formatted, select the entire contents of the text editor then copy-and-paste the content into the Latitude and Longitude columns in the Trip Planner sheet of the CAE “Route Planning Template” Excel spreadsheet Figure A-5). Once in the spreadsheet, an appropriate speed value should be added into the Speed column. The spreadsheet will then automatically generate associated time values for each waypoint in the Output columns.

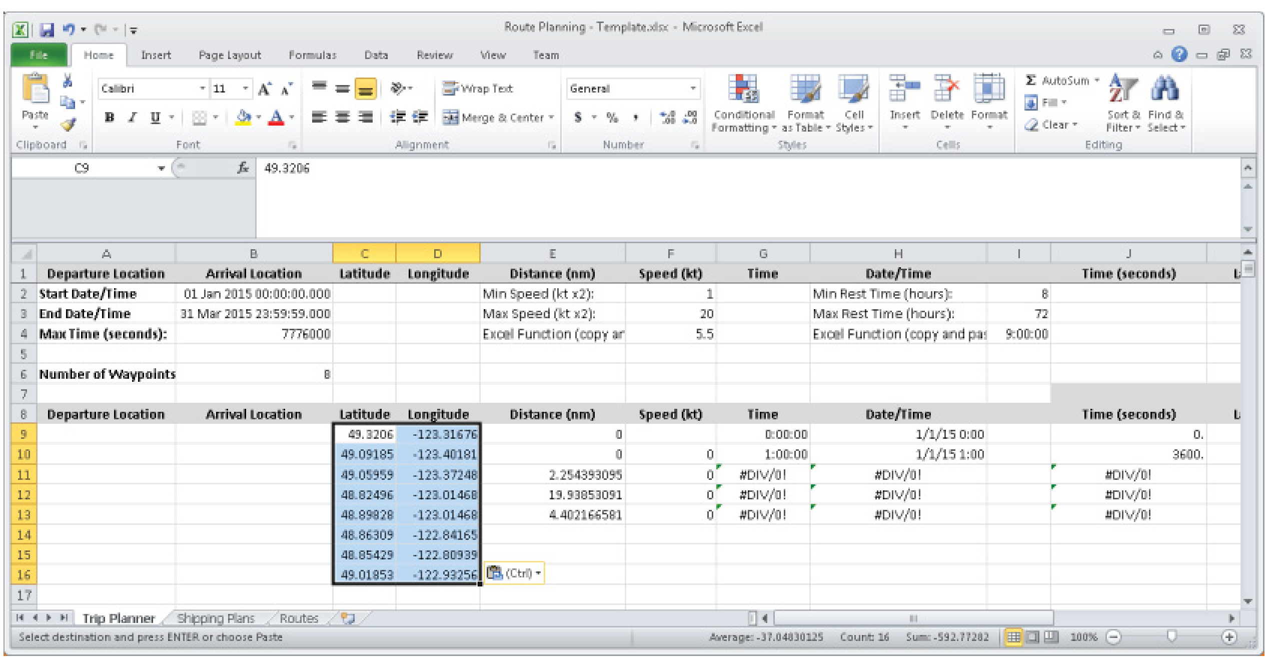
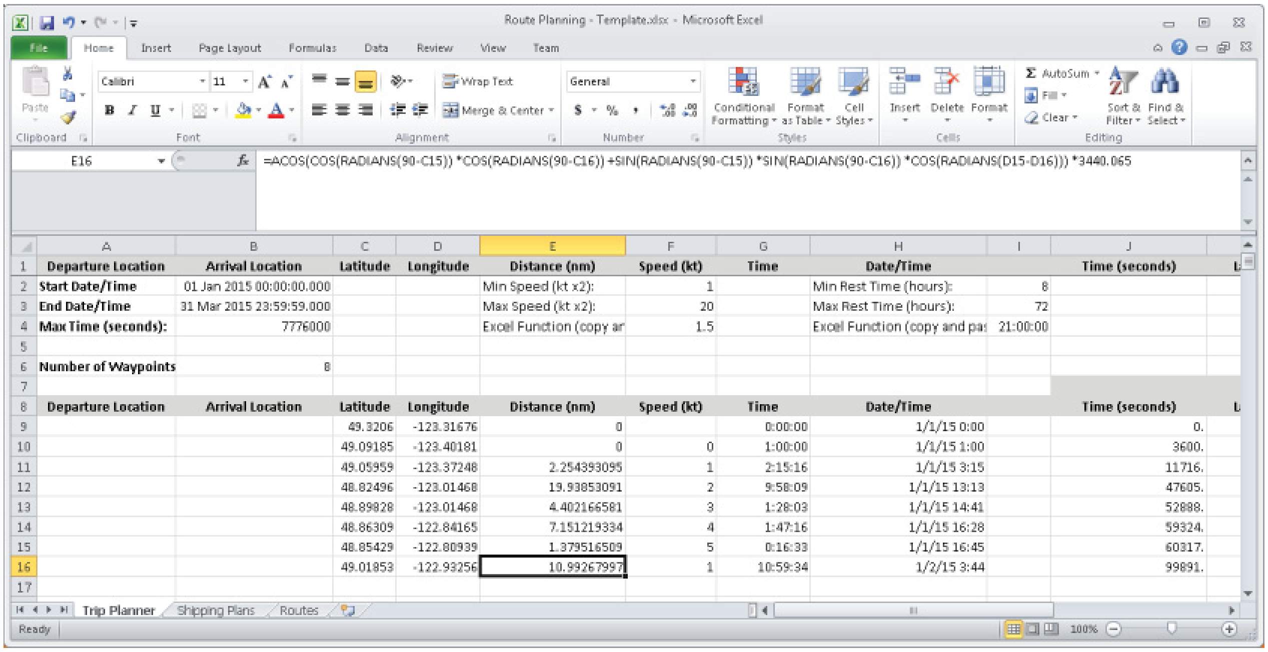


Figure A-5: Copying the Initial Points into the Route Planning Spreadsheet

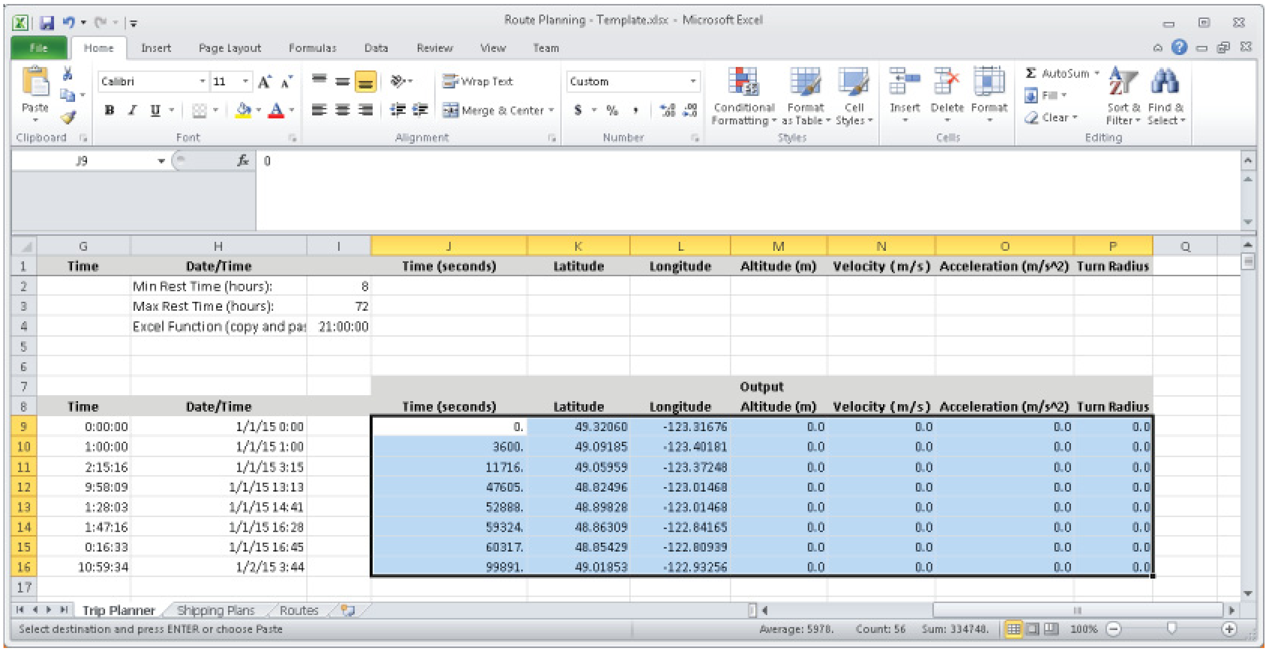


	A	B	C	D	E	F	G	H	I	J
1	Departure Location	Arrival Location	Latitude	Longitude	Distance (nm)	Speed (kt)	Time	Date/Time		Time (seconds)
2	Start Date/Time	01 Jan 2015 00:00:00.000			Min Speed (kt x2):	1		Min Rest Time (hours):	8	
3	End Date/Time	31 Mar 2015 23:59:59.000			Max Speed (kt x2):	20		Max Rest Time (hours):	72	
4	Max Time (seconds):	7776000			Excel Function (copy ar	1.5		Excel Function (copy and pa:	21:00:00	
5										
6	Number of Waypoints	8								
7										
8	Departure Location	Arrival Location	Latitude	Longitude	Distance (nm)	Speed (kt)	Time	Date/Time		Time (seconds)
9			49.3206	-123.31676	0		0:00:00	1/1/15 0:00		0.
10			49.09185	-123.40181	0	0	1:00:00	1/1/15 1:00		3600.
11			49.05959	-123.37248	2.254393095	1	2:15:16	1/1/15 3:15		11716.
12			48.82496	-123.01468	19.93853091	2	9:58:09	1/1/15 13:13		47605.
13			48.89828	-123.01468	4.402166581	3	1:28:03	1/1/15 14:41		52888.
14			48.86309	-122.84165	7.151219334	4	1:47:16	1/1/15 16:28		59324.
15			48.85429	-122.80939	1.379516509	5	0:16:33	1/1/15 16:45		60317.
16			49.01853	-122.93256	10.99267997	1	10:59:34	1/2/15 3:44		99891.
17										

Figure A-6: Adding Speed Values in the Route Planning Spreadsheet

Once in the spreadsheet, the route data can be manipulated in various ways for a variety of purposes. Entire sections of the route can be copied and pasted to the bottom of spreadsheet to have an object repeat the selected section of the route. The speed of the route can be randomized by replacing cells in the Speed columns with Excel function in cell F4. The object can be configured to rest at a certain point by making a copy of the point and changing the value in the Time column to either a fixed time or a randomized time by replacing the cell with Excel function in cell I4.

The spreadsheet will automatically generate the equivalent Time, Latitude and Longitude data for the STK waypoints in the Output column. Additional customization can be applied by modifying the values of the Altitude column for Aircraft object. The values in the Velocity and Acceleration columns should remain “0.0” since the route planner spreadsheet method uses STK’s Specific Time route calculation method. Once the user is satisfied with the route, select and copy the entire Output section from the spreadsheet (Figure A-7).

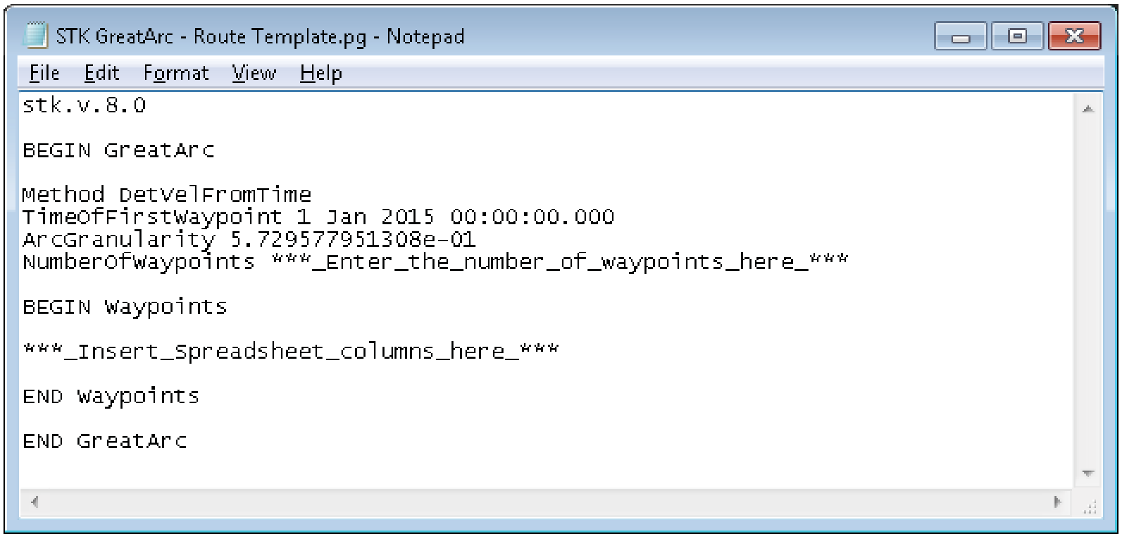


	G	H	I	J	K	L	M	N	O	P
1	Time	Date/Time		Time (seconds)	Latitude	Longitude	Altitude (m)	Velocity (m/s)	Acceleration (m/s^2)	Turn Radius
2		Min Rest Time (hours):	8							
3		Max Rest Time (hours):	72							
4		Excel Function (copy and pa	21:00:00							
5										
6										
7							Output			
8	Time	Date/Time		Time (seconds)	Latitude	Longitude	Altitude (m)	Velocity (m/s)	Acceleration (m/s^2)	Turn Radius
9	0:00:00	1/1/15 0:00		0.	49.32060	-123.31676	0.0	0.0	0.0	0.0
10	1:00:00	1/1/15 1:00		3600.	49.09185	-123.40181	0.0	0.0	0.0	0.0
11	2:15:16	1/1/15 3:15		11716.	49.05959	-123.37248	0.0	0.0	0.0	0.0
12	9:58:09	1/1/15 13:13		47605.	48.82496	-123.01468	0.0	0.0	0.0	0.0
13	1:28:03	1/1/15 14:41		52888.	48.89828	-123.01468	0.0	0.0	0.0	0.0
14	1:47:16	1/1/15 16:28		59324.	48.86309	-122.84165	0.0	0.0	0.0	0.0
15	0:16:33	1/1/15 16:45		60317.	48.85429	-122.80939	0.0	0.0	0.0	0.0
16	10:59:34	1/2/15 3:44		99891.	49.01853	-122.93256	0.0	0.0	0.0	0.0

Figure A-7: Copying the Output Columns from the Route Planning Spreadsheet

Open the "`STK GreatArc – Route Template.pg`" STK Great Arc Propagator file (Figure A-8) and replace the "`***_Insert_Spreadsheet_columns_here_***`" line with the contents of the spreadsheet. Once the copy and paste is complete, replace the "`***_Enter_the_number_of_waypoints_here_***`" line in the Great Arc Propagator file with an integer value indicating the number of waypoints in the file (Figure A-9). Save the file and ensure that it remains a STK Great Arc Propagator file with a ".pg" extension.

Additional information concerning the STK Great Arc Propagator file structure can be found at http://help.agi.com/stk/10.1.3/index.html?page=source%2Fstk%2Fimportfiles-05.htm.

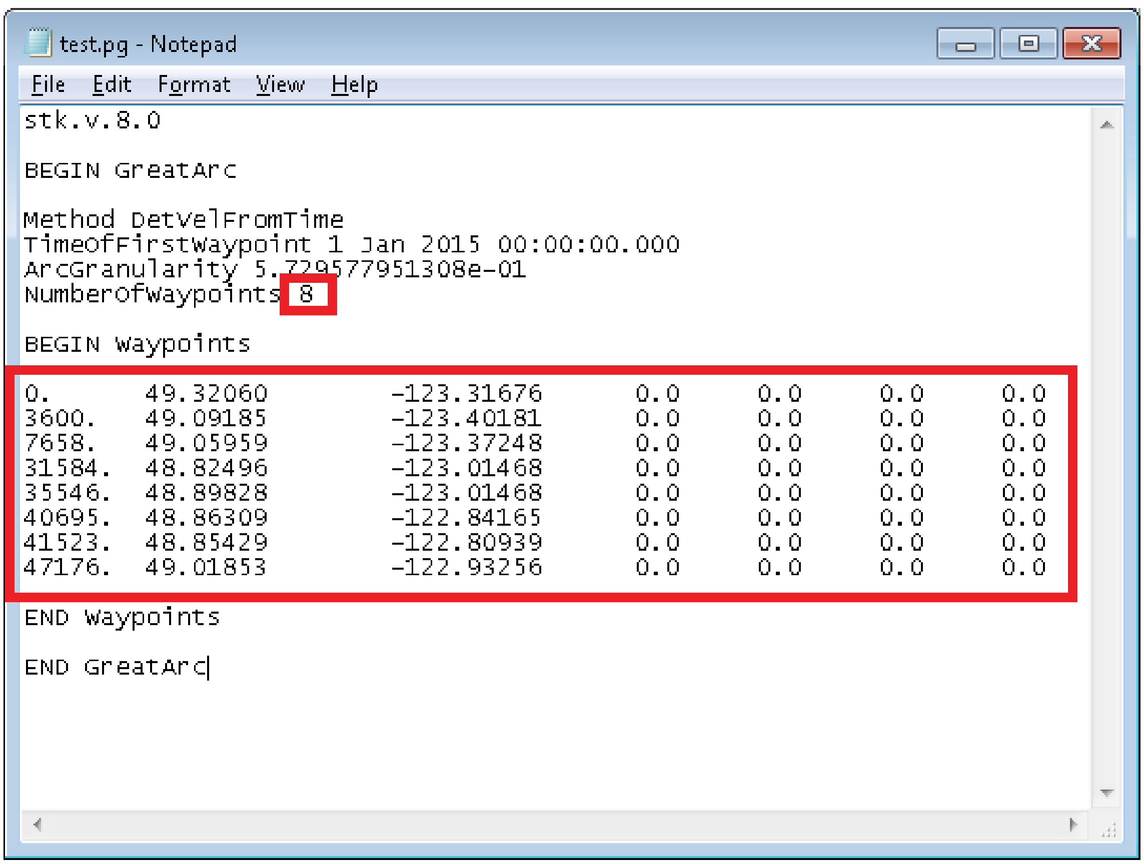


STK GreatArc - Route Template.pg - Notepad

File Edit Format View Help

```
stk.v.8.0

BEGIN GreatArc

Method DetVelFromTime
TimeOfFirstWaypoint 1 Jan 2015 00:00:00.000
ArcGranularity 5.729577951308e-01
NumberOfWaypoints ***_Enter_the_number_of_waypoints_here_***

BEGIN Waypoints

***_Insert_Spreadsheet_columns_here_***

END Waypoints

END GreatArc
```

Figure A-8: STK Formatted Great Arc Propagator Route Template File



test.pg - Notepad

File Edit Format View Help

```
stk.v.8.0

BEGIN GreatArc

Method DetVelFromTime
TimeOfFirstWaypoint 1 Jan 2015 00:00:00.000
ArcGranularity 5.729577951308e-01
NumberOfWaypoints 8

BEGIN Waypoints

0.      49.32060      -123.31676      0.0      0.0      0.0      0.0
3600.   49.09185      -123.40181      0.0      0.0      0.0      0.0
7658.   49.05959      -123.37248      0.0      0.0      0.0      0.0
31584.  48.82496      -123.01468      0.0      0.0      0.0      0.0
35546.  48.89828      -123.01468      0.0      0.0      0.0      0.0
40695.  48.86309      -122.84165      0.0      0.0      0.0      0.0
41523.  48.85429      -122.80939      0.0      0.0      0.0      0.0
47176.  49.01853      -122.93256      0.0      0.0      0.0      0.0

END Waypoints

END GreatArc
```

Figure A-9: Pasting Output from the Route Planning Spreadsheet into a STK Formatted Great Arc Propagator File

Finally, open the object properties in STK and select the “Import from File…” button in the Basic → Route page (Figure A-10).STK will accept the file if it is properly formatted, and the object will take on the route created in the spreadsheet.

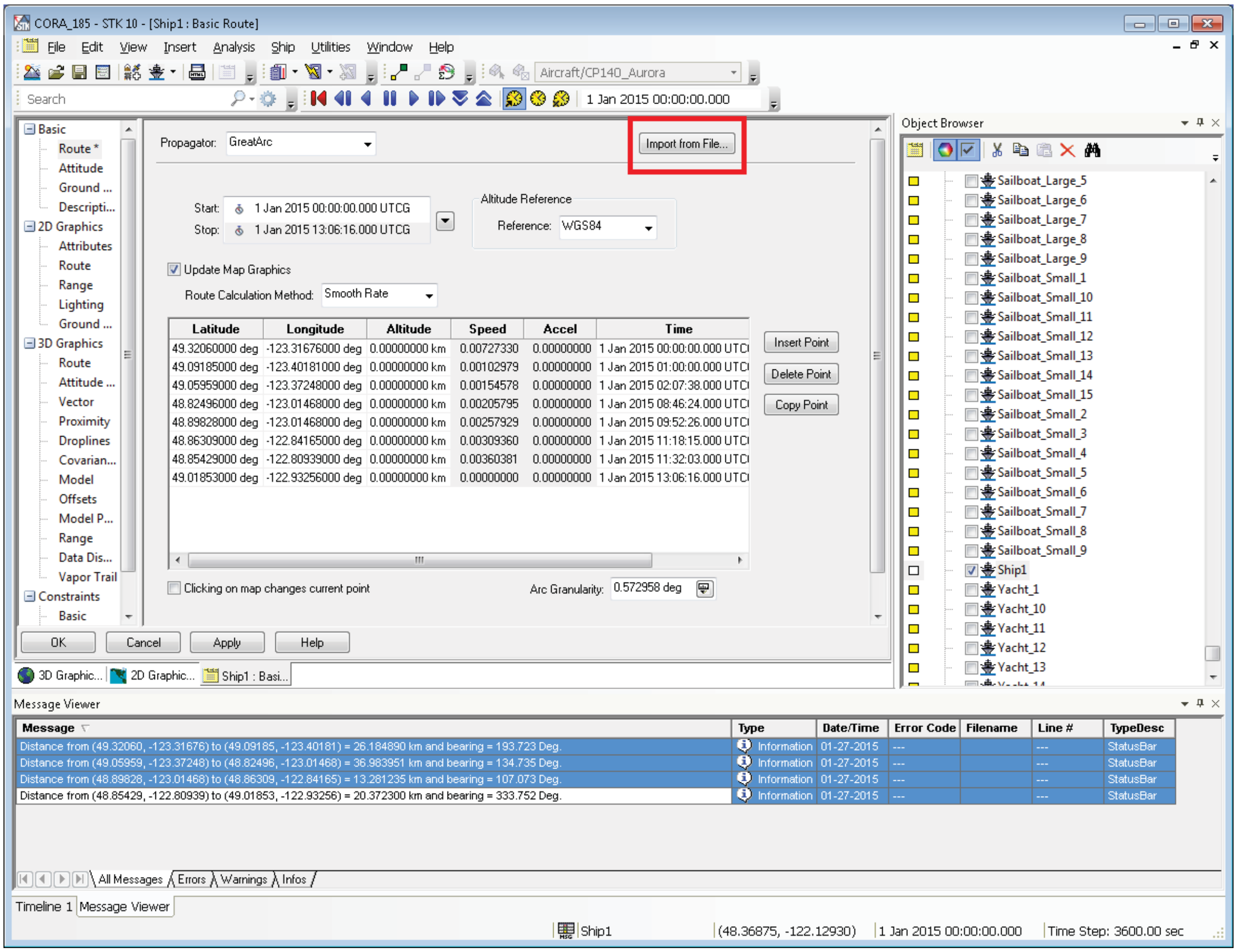


Figure A-10: Importing a STK Great Arc Propagator File for an STK Object

APPENDIX B STK INSTALLATION AND CONFIGURATION INSTRUCTIONS

Following is a set of brief instructions describing how to install the free version of STK 10.1.3, the free additional 3D models and the delivered Task 185 scenario.

1. Execute the `STK1013OneClickInstall.exe` that can be downloaded from the AGI website. The installer will request a free STK license from AGI. This can be completed by following the instructions listed by installer. It will likely require the creation of an account and registering with AGI, as the license is associated with the individual computer on which STK is installed.

2. Install the additional 3D models downloaded from AGI's 3D model repository to the STK installation:

    a. Copy and unzip the contents of the `commuter.zip` file from the delivered files into the `C:\Program Files (x86)\AGI\STK 10\STKData\VO\Models\Air` folder.

    b. Copy and unzip the contents of the `cruise_liner.zip` file from the delivered files into the `C:\Program Files (x86)\AGI\STK 10\STKData\VO\Models\Sea` folder.

    c. Copy and unzip the contents of the `opc.zip` file from the delivered files into the `C:\Program Files (x86)\AGI\STK 10\STKData\VO\Models\Sea` folder.

    d. Copy and unzip the contents of the `rubber_boat.zip` file from the delivered files into the `C:\Program Files (x86)\AGI\STK 10\STKData\VO\Models\Sea` folder.

    e. Copy and unzip the contents of the `septar.zip` file from the delivered files into the `C:\Program Files (x86)\AGI\STK 10\STKData\VO\Models\Sea` folder.

    f. Copy and unzip the contents of the `threat_freighter.zip` file from the delivered files into the `C:\Program Files (x86)\AGI\STK 10\STKData\VO\Models\Sea` folder.

    g. Copy and unzip the contents of the `threat_ type_23_frigate.zip` file from the delivered files into the `C:\Program Files (x86)\AGI\STK 10\STKData\VO\Models\Sea` folder.

3. Install the delivered scenario onto the local machine.

    a. Copy the entire `CORA_185` folder from the delivered files to `%USERPROFILE%\Documents\STK 10\` folder.

4. Execute the STK 10 application and select to open the `CORA_185` scenario. Executing STK and loading the scenario for the first time many take several minutes. Please be patient and allow the process to complete.

APPENDIX C POTENTIAL FUTURE STK MODEL SPECIFICATIONS

This appendix contains a listing of the specifications associated with potentially future desirable attributes that could be implemented in the Pro version of STK with custom add-on modules. The primary source for the information contained within this appendix was the STK Help files freely accessible online at: http://www.agi.com/resources/help/online/stk/10.1/

C.1 STK Specifics for Potential Follow On Work

Depending on the level of detail that the user / analyst wishes to explore (based on the activity requirements) STK is capable of modelling a variety of highly detailed aspects associated with radar sensors and communication systems (transmitters and receivers), including consideration for certain atmospheric and target phenomena. These detailed functionalities require licensing of the appropriate add-on modules for STK (namely STK Radar and STK Communications). If detailed, physics-based interaction analysis amongst sensors, targets and the environment is not necessary, then STK can accomplish some highly useful operational planning type assessments using the baseline STK Pro capabilities along with the STK Coverage module. The STK Radar and STK Communications modules provide the ability to invoke highly detailed modelling of sensors and systems in those domains.

The following sections identify some of the characteristics and parameters that can be included in the various add-on modules depending on the aims and objectives of the users and analysts.

C.1.1 Radar Sensors

Within STK Radar there are a few different types of radars that can be defined; these include:

- Monostatic;
- Bistatic receiver and transmitter;
- Search / track radar; and
- Synthetic aperture radar (SAR).

One can also define jammers and detailed antenna models, as well as a variety of effects associated with specific types of atmospheric phenomena, such as rain, gaseous absorption, clouds, fog and the troposphere.

The basic properties for a radar object in STK include the following:

- Specifications:
    - The operating frequency or wavelength of the radar system;
    - The peak output power of the transmitter;

- Radio Frequency Filter:
  - When used, the respective bandwidths are used to determine transmitter signal and receiver bandwidths;
- Polarization (select from types available); and
- Gains and Losses (single values entered by user in a list).

The user can also define a variety of highly details system specifications (system operating temperature, receiver noise, transmission line loss and temperature, antenna noise) to help simulate real-world RF situations more accurately if necessary.

C.1.2 Radar Cross-Section Property

Within STK, the RF properties for scenario objects include a page for radar cross-section (RCS). The RCS property is defined in association with one or more user-specified RF band(s). The minimum frequency for the RF bands is 3 MHz while the maximum is 300 GHz; the user can insert new bands and then must specify the minimum frequency and maximum frequency associated with that band.

The user must then specify which of four Compute Types will be used:

- A Constant Value;
- An External File, which defines an Aspect Dependent RCS;
- A Script Plug-in, which computes aspect dependent RCS values for each time step in a radar computation based on a set of Input Arguments including Frequency, Incident Angles and Vectors, Reflected Angles and Vectors; and
- A RCS COM Plug-in, if available and properly registered in the local machine.

The user must then select one of five Swerling cases to account for RCS fluctuations. These cases are situation and case dependent and must be reviewed by the user / analyst in the STK Help documentation.

C.1.3 Radar Plugin Points

STK Radar also provides plugin points for the following aspects:

- Custom antenna gain;
- Absorption loss model;
- Rain loss model;
- Custom loss model;

- Filter;
- Search / track constraint;
- SAR constraint; and
- Radar cross section.

C.1.4 Communication Systems

STK Communications is required to define transmitter and receiver objects.

Transmitters

A Transmitter object in STK models the characteristics of the transmitter, the antenna it uses and the environment in which it operates. The basic properties of a Simple Transmitter object are:

- Carrier frequency;
- Effective Isotropic Radiated Power;
- Data rate (in bits per second);
- Polarization (selectable);
- Modulator type (selectable or user-defined);
- Filter (selectable); and
- Additional gains and losses.

NOTE that in addition to Simple Transmitters there are seven other types of transmitters that can be implemented:

- Cable;
- Medium;
- Complex;
- Multi-beam;
- Plug-in;
- Laser; and

- GPS satellite.

The characteristics of frequency, power, data rate, polarization and filters tend to be common among most of the transmitter types, although there are some specific aspects for the different types depending on the required level of detail.

Receivers

A Receiver object in STK models the characteristics of the receiver, the antenna it uses and the environment in which it operates. The basic properties of a Simple Receiver object are:

- Frequency (desired value or Auto Track option);
- System gain divided by system temperature;
- Polarization;
- Rain model (selectable);
- Demodulator type (selectable or user-defined);
- Filter (selectable); and
- Additional gains and losses.

NOTE that in addition to Simple Receivers there are seven other types of transmitters that can be implemented:

- Cable;
- Medium;
- Complex;
- Multi-beam;
- Laser;
- Plug-in Laser; and
- Plug-in RF.

C.1.5 Communications Plugin Points

STK Radar also provides plugin points to allow users / developers to specify their own custom models. Plugin points are available for the following aspects:

- Transmitter model;
- Receiver model;
- Custom antenna gain;
- Absorption loss model;
- Rain loss model;
- Custom loss model;
- Antenna multi-beam selection strategy;
- Communication system link selection strategy;
- Modulator;
- Demodulator;
- Filter; and
- Communication constraint.

C.1.6 STK Coverage

As identified in the STK Help files, the STK Coverage module allows the user to "analyze the global or regional coverage provided by one or more assets while considering all access constraints." To facilitate this type of analysis, the STK Coverage module provides two additional object classes: Coverage Definition, and Figure of Merit.

The Coverage Definition object allows the user to define and specify:

- The coverage area and an associated grid point spacing (resolution) over the area;
- The STK objects providing the coverage; and
- The time period of interest.

The results of a coverage analysis can be displayed in both the 2D and 3D Graphics Windows, as well as in the form of a text-based coverage report. Table C-1 identifies the types of coverage reports and graphs as well as figures of merit available through STK Coverage as listed in the STK Help files:

Table C-1: Coverage Reports and Graphs

Coverage Reports and Graphs	
Region Coverage	Access Duration
Region Full Coverage	Coverage by Asset
Region Pass Coverage	Gap Duration
Point Coverage	Gaps in Global Coverage
Point Daily Coverage	Global Coverage
Point Probability of Coverage	Percent Coverage
Coverage by Latitude	Time to Cover by Region
Figures of Merit	
Measuring Simple Coverage	Number of Accesses
Number of Assets	Access Separation
Coverage Time	Number of Gaps
Revisit Time	Average Length of Coverage Gap
Access Duration	Response Time

C.1.7 STK EOIR

The STK Help files identify a STK EOIR (Electro Optical Infrared) module; however, it specifically indicates that the capability, which was developed by the Space Dynamics Laboratory (SDL), models “detection, tracking, and imaging performance of electro-optical and infrared sensors for earth science, missile defense, and space situational awareness applications.” The Canadian representative for AGI was asked if STK had the capability to perform EOIR sensor modelling in the maritime coastal surveillance context and no specific answer was provided.

APPENDIX D SAMPLE ACCESS CALCULATIONS

The first set of Access calculations are for the CP140 aircraft object against the two outer MARPAC Area Target objects. For these calculations, the Constraints (azimuth, elevation and range) that were assigned to the CP140 object are taken into account. Figure D-1 depicts the Access calculation set-up.

Figure D-1: CP140 Access Setup

D.1 CP140 Aircraft with Basic Constraints – to – MARPAC Outer North

```
28 Jan 2015 18:51:41
Aircraft-CP140_Aurora-To-AreaTarget-MARPAC_Outer_North:  Access Summary Report
CP140_Aurora-To-MARPAC_Outer_North
----------------------------------
                    Access       Start Time (UTCG)          Stop Time (UTCG)        Duration (sec)
                    ------    ------------------------    ------------------------    --------------
                         1     5 Jan 2015 00:19:32.665     5 Jan 2015 02:28:25.453          7732.788
                         2     9 Jan 2015 11:28:27.261     9 Jan 2015 14:47:53.673         11966.412
                         3    14 Jan 2015 06:31:51.665    14 Jan 2015 08:40:44.784          7733.119
                         4    17 Jan 2015 02:40:47.247    17 Jan 2015 06:00:12.673         11965.426
                         5    21 Jan 2015 18:44:10.665    21 Jan 2015 20:53:03.784          7733.119
                         6    25 Jan 2015 19:53:06.261    25 Jan 2015 23:12:32.673         11966.412
                         7    30 Jan 2015 14:56:29.665    30 Jan 2015 17:05:22.784          7733.119
                         8     3 Feb 2015 16:05:25.261     3 Feb 2015 19:24:51.673         11966.412
                         9     7 Feb 2015 02:08:48.698     7 Feb 2015 04:17:41.784          7733.086
                        10    11 Feb 2015 02:17:44.261    11 Feb 2015 05:37:10.673         11966.412
                        11    14 Feb 2015 17:21:08.665    14 Feb 2015 19:30:01.453          7732.788
                        12    19 Feb 2015 07:30:03.261    19 Feb 2015 10:49:29.673         11966.412
                        13    24 Feb 2015 08:33:27.665    24 Feb 2015 10:42:20.784          7733.119
                        14    28 Feb 2015 21:42:23.247     1 Mar 2015 01:01:48.673         11965.426
                        15     5 Mar 2015 15:45:46.665     5 Mar 2015 17:54:39.784          7733.119
                        16     8 Mar 2015 08:54:42.261     8 Mar 2015 12:14:08.673         11966.412
                        17    11 Mar 2015 06:58:05.665    11 Mar 2015 09:06:58.784          7733.119
                        18    16 Mar 2015 00:07:01.261    16 Mar 2015 03:26:27.673         11966.412
                        19    19 Mar 2015 00:10:24.698    19 Mar 2015 02:19:17.784          7733.086
                        20    23 Mar 2015 22:19:20.261    24 Mar 2015 01:38:46.673         11966.412
                        21    26 Mar 2015 16:22:44.665    26 Mar 2015 18:31:37.453          7732.788
                        22    30 Mar 2015 09:31:39.261    30 Mar 2015 12:51:05.673         11966.412
                        23     3 Apr 2015 23:35:03.665     4 Apr 2015 01:43:56.784          7733.119
                        24     8 Apr 2015 09:43:59.247     8 Apr 2015 13:03:24.673         11965.426

Global Statistics
-----------------
Min Duration            11    14 Feb 2015 17:21:08.665    14 Feb 2015 19:30:01.453          7732.788
Max Duration             6    25 Jan 2015 19:53:06.261    25 Jan 2015 23:12:32.673         11966.412
```

```
Mean Duration                                                   9849.598
Total Duration                                                236390.353
```

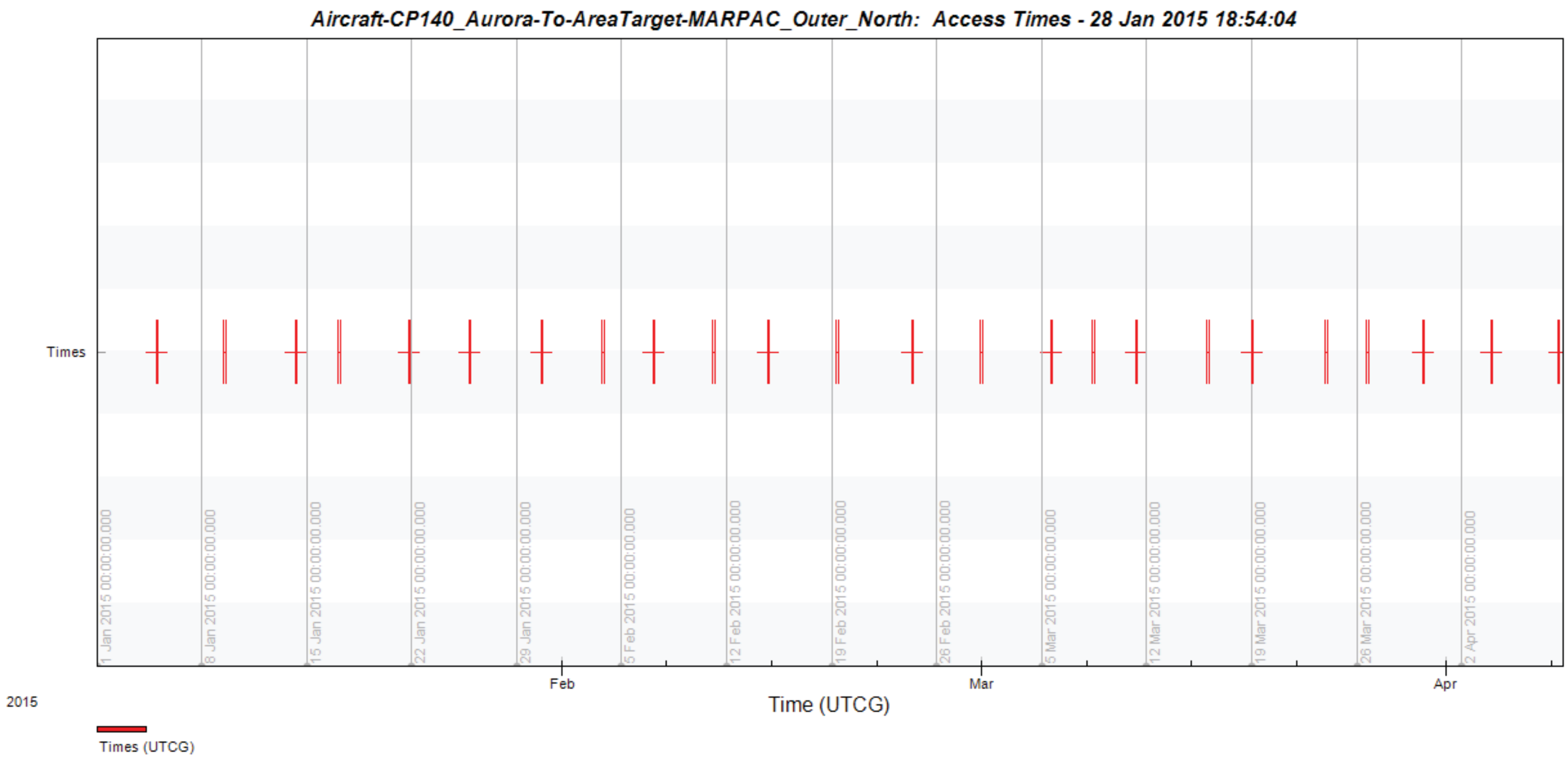


Figure D-2: Sample CP140 Access to Outer North AOR Results

D.2 CP140 Aircraft with Basic Constraints – to – MARPAC Outer South

```
28 Jan 2015 18:56:05
Aircraft-CP140_Aurora-To-AreaTarget-MARPAC_Outer_South:  Access Summary Report
CP140_Aurora-To-MARPAC_Outer_South
----------------------------------
```

Access	Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
1	5 Jan 2015 01:24:04.318	5 Jan 2015 02:53:41.222	5376.904
2	5 Jan 2015 06:05:05.876	5 Jan 2015 06:31:18.169	1572.293
3	9 Jan 2015 11:03:40.073	9 Jan 2015 12:20:26.479	4606.405
4	9 Jan 2015 13:48:01.228	9 Jan 2015 18:04:46.876	15405.647
5	14 Jan 2015 07:36:23.701	14 Jan 2015 09:06:00.222	5376.521
6	14 Jan 2015 12:17:24.876	14 Jan 2015 12:43:37.308	1572.432
7	17 Jan 2015 02:15:59.818	17 Jan 2015 03:32:46.479	4606.660
8	17 Jan 2015 05:00:20.228	17 Jan 2015 09:17:05.876	15405.647
9	21 Jan 2015 19:48:43.318	21 Jan 2015 21:18:19.222	5375.904
10	22 Jan 2015 00:29:43.876	22 Jan 2015 00:55:56.308	1572.432
11	25 Jan 2015 19:28:19.073	25 Jan 2015 20:45:05.479	4606.405
12	25 Jan 2015 22:12:39.731	26 Jan 2015 02:29:24.889	15405.158
13	30 Jan 2015 16:01:02.318	30 Jan 2015 17:30:38.433	5376.114
14	30 Jan 2015 20:42:02.876	30 Jan 2015 21:08:15.308	1572.432
15	3 Feb 2015 15:40:38.073	3 Feb 2015 16:57:24.479	4606.405
16	3 Feb 2015 18:24:58.731	3 Feb 2015 22:41:43.889	15405.158
17	7 Feb 2015 03:13:21.318	7 Feb 2015 04:42:57.433	5376.114
18	7 Feb 2015 07:54:22.035	7 Feb 2015 08:20:34.308	1572.273
19	11 Feb 2015 01:52:57.073	11 Feb 2015 03:09:43.479	4606.405
20	11 Feb 2015 04:37:17.731	11 Feb 2015 08:54:03.876	15406.144
21	14 Feb 2015 18:25:40.318	14 Feb 2015 19:55:17.222	5376.904
22	14 Feb 2015 23:06:41.876	14 Feb 2015 23:32:54.169	1572.293
23	19 Feb 2015 07:05:16.073	19 Feb 2015 08:22:02.479	4606.405
24	19 Feb 2015 09:49:37.228	19 Feb 2015 14:06:22.876	15405.647
25	24 Feb 2015 09:37:59.701	24 Feb 2015 11:07:36.222	5376.521
26	24 Feb 2015 14:19:00.876	24 Feb 2015 14:45:13.308	1572.432
27	28 Feb 2015 21:17:35.818	28 Feb 2015 22:34:22.479	4606.660
28	1 Mar 2015 00:01:56.228	1 Mar 2015 04:18:41.876	15405.647
29	5 Mar 2015 16:50:19.318	5 Mar 2015 18:19:55.222	5375.904

30	5 Mar 2015 21:31:19.876	5 Mar 2015 21:57:32.308	1572.432
31	8 Mar 2015 08:29:55.073	8 Mar 2015 09:46:41.479	4606.405
32	8 Mar 2015 11:14:15.731	8 Mar 2015 15:31:00.889	15405.158
33	11 Mar 2015 08:02:38.318	11 Mar 2015 09:32:14.433	5376.114
34	11 Mar 2015 12:43:38.876	11 Mar 2015 13:09:51.308	1572.432
35	15 Mar 2015 23:42:14.073	16 Mar 2015 00:59:00.479	4606.405
36	16 Mar 2015 02:26:34.731	16 Mar 2015 06:43:19.889	15405.158
37	19 Mar 2015 01:14:57.318	19 Mar 2015 02:44:33.433	5376.114
38	19 Mar 2015 05:55:58.035	19 Mar 2015 06:22:10.308	1572.273
39	23 Mar 2015 21:54:33.073	23 Mar 2015 23:11:19.479	4606.405
40	24 Mar 2015 00:38:53.731	24 Mar 2015 04:55:38.889	15405.158
41	26 Mar 2015 17:27:16.318	26 Mar 2015 18:56:53.222	5376.904
42	26 Mar 2015 22:08:17.876	26 Mar 2015 22:34:30.169	1572.293
43	30 Mar 2015 09:06:52.073	30 Mar 2015 10:23:38.479	4606.405
44	30 Mar 2015 11:51:13.228	30 Mar 2015 16:07:58.876	15405.647
45	4 Apr 2015 00:39:35.701	4 Apr 2015 02:09:12.222	5376.521
46	4 Apr 2015 05:20:36.876	4 Apr 2015 05:46:49.308	1572.432
47	8 Apr 2015 09:19:11.818	8 Apr 2015 10:35:58.479	4606.660
48	8 Apr 2015 12:03:32.228	8 Apr 2015 16:20:17.876	15405.647

Global Statistics

Min Duration	38	19 Mar 2015 05:55:58.035	19 Mar 2015 06:22:10.308	1572.273
Max Duration	20	11 Feb 2015 04:37:17.731	11 Feb 2015 08:54:03.876	15406.144
Mean Duration				6740.176
Total Duration				323528.432

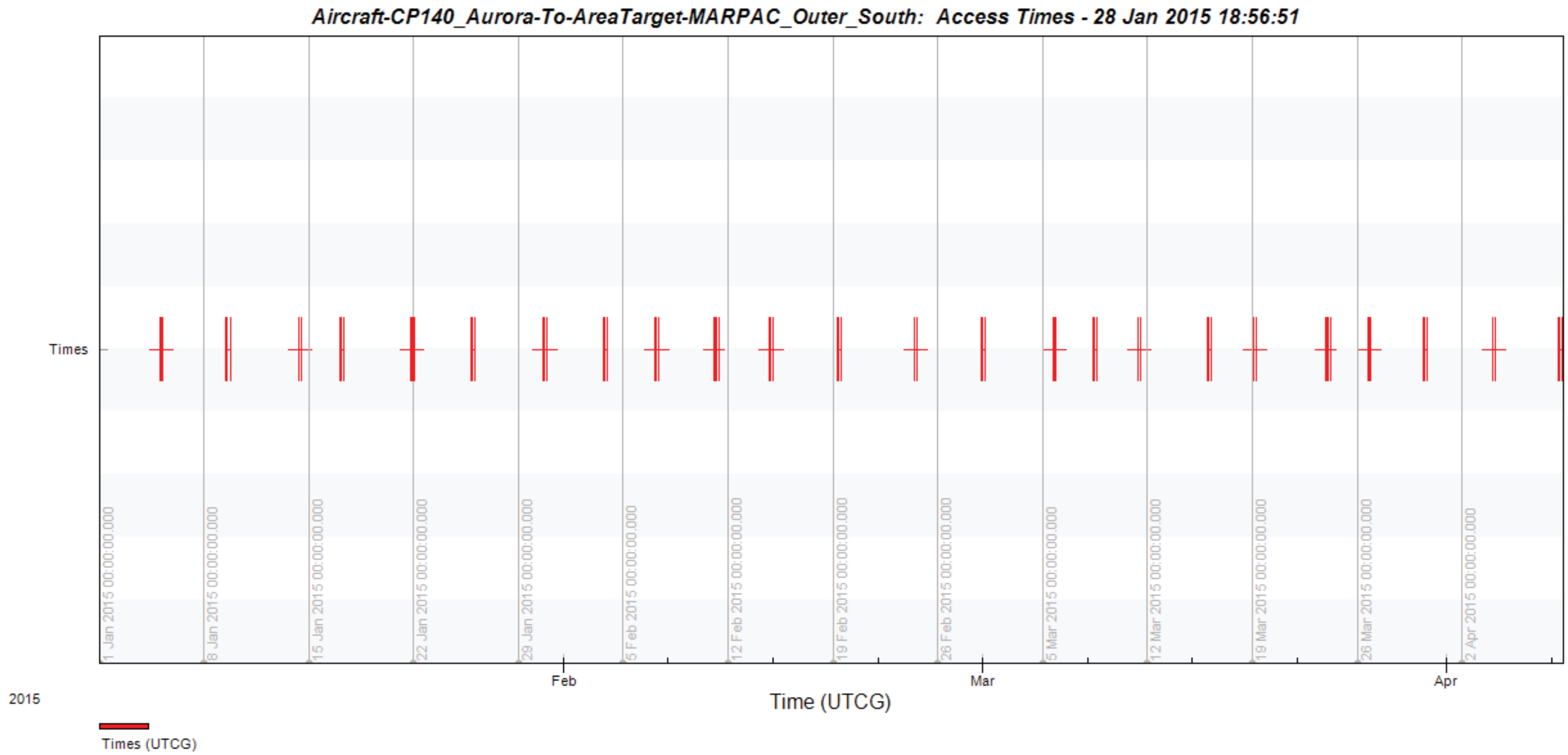


Figure D-3: Sample CP140 Access to Outer South AOR Results

The next example is based on CP140 Access calculations against the two Outer and two Inner MARPAC areas for the duration of the scenario time period. The pie chart (Figure D-4) depicts Cumulative Dwell of the four areas combined throughout the scenario period. The result is that, based on the flight paths, mission times, Access Constraints and MARPAC area definitions, the CP140 can observe at least some part of the four areas for 7.7% of the full three month period.

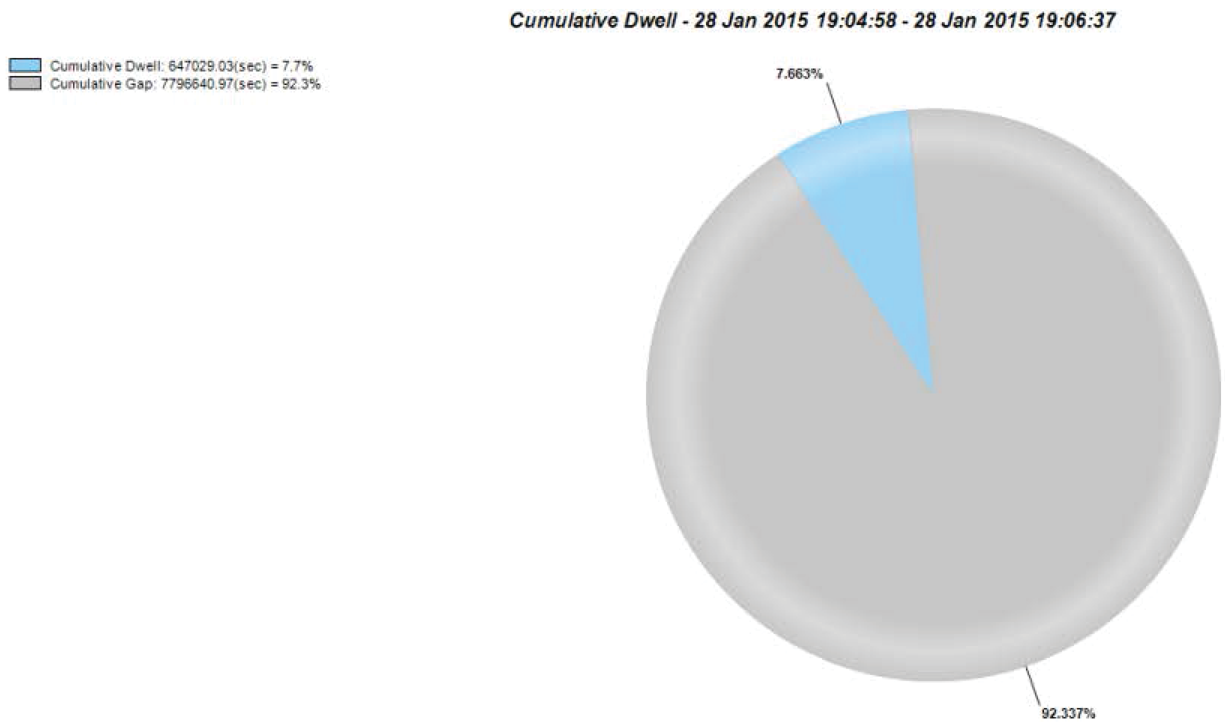


Figure D-4: Sample CP140 Cumulative Dwell Access Results

D.3 MARPAC Full Area – to – Satellite Objects

This next set of Access calculations are for a group of space-based assets (satellites) against the full MARPAC area (MARPAC_Full). For this calculation, the Access computations are done from the perspective of the Area Target object – that is, the calculation looks for times when any part of the MARPAC_Full area is in direct line of sight of any of the satellites. Because the satellites are present throughout the scenario period and their orbital periods are relatively short in duration, Access calculations for this set-up produce a large quantity of results. Therefore, the calculation period has been reduced to the first two weeks of the full time period. Even for this shortened period, the text report is far too lengthy to include in this document; only the graphical outputs are presented.

The first graphic (Figure D-5) is the basic Access from the MARPAC_Full area to each of the satellites.

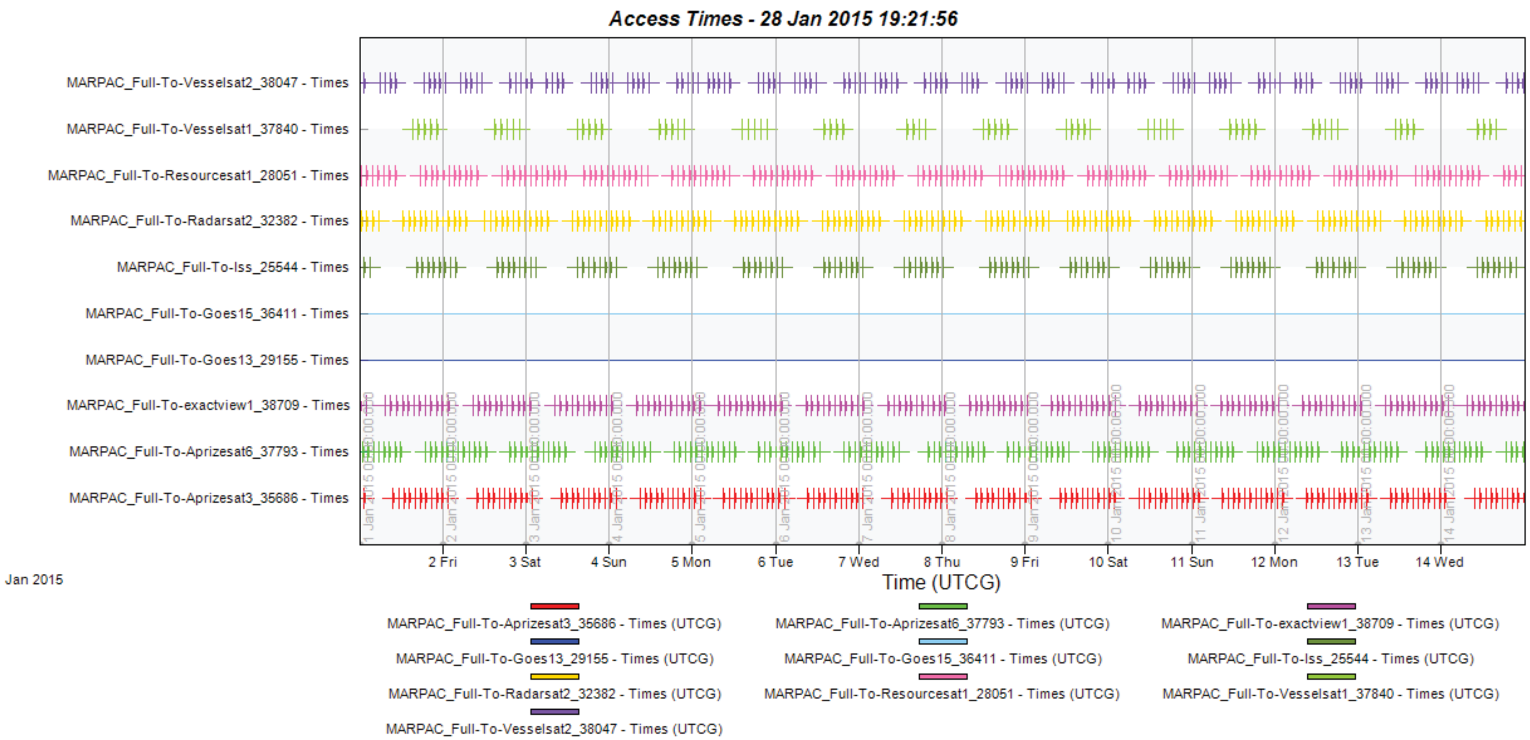


Figure D-5: Sample Satellite Access to MARPAC AOR

One can see that the GOES satellites are always within view of the area because they are in a geosynchronous orbit over the western hemisphere.

For the second graphic (Figure D-6) the GOES satellites have been excluded from the calculation to achieve aims of the demonstration. The graphic shows the Cumulative Dwell calculation – that is, the cumulative amount of time that any part of the MARPAC_Full area is in line of sight of any of the satellites (excluding GOES assets), as a percentage of the two week analysis period. The result can be interpreted as follows: the group of satellites operating as a collective resource have line of sight access to at least a single spot within the MARPAC_FULL area for 57.3% of the full two week period.

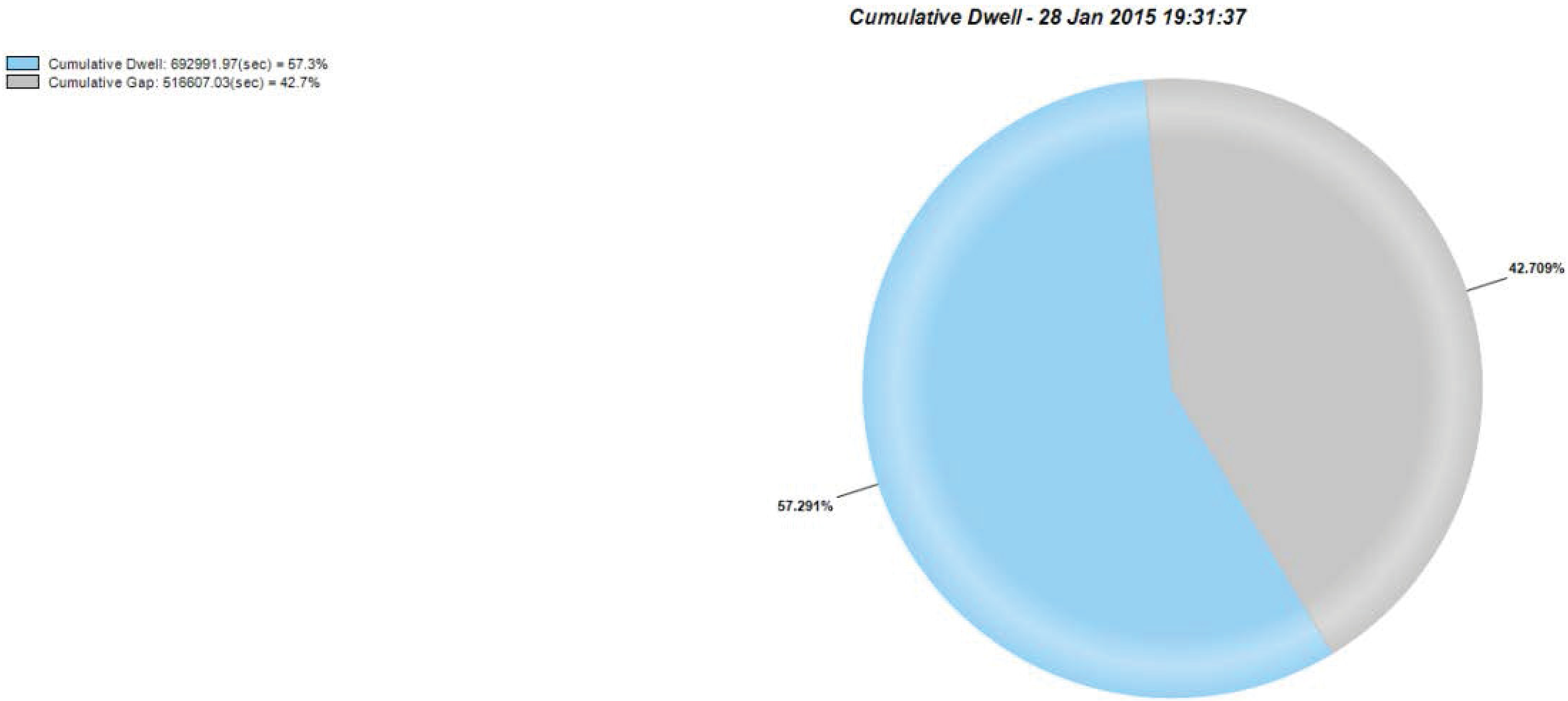


Figure D-6: Sample Satellite Cumulative Dwell

D.4 CP140 Aircraft with Basic Constraints – to – Cargo Vessels #1 through #10

This set of calculations was done for the CP140 Aircraft Object against the first 10 Cargo Vessels. The time period used was the first two weeks of the scenario to keep the result output size reasonable for reporting. Following are the text and graphic results (Figure D-7).

```
Aircraft-CP140_Aurora-To-Ship-Cargo_Vessel_1, Ship-Cargo_Vessel_10, Ship-Cargo_Vessel_2, Ship-
Cargo_Vessel_3, Ship-Cargo_Vessel_4, Ship-Cargo_Vessel_5, Ship-Cargo_Vessel_6, Ship-Cargo_Vessel_7, Ship-
Cargo_Vessel_8, Ship-Cargo_Vessel_9:  Access Summary Report


CP140_Aurora-To-Cargo_Vessel_1
------------------------------
                  Access      Start Time (UTCG)          Stop Time (UTCG)        Duration (sec)
                  ------   ------------------------   ------------------------   --------------
                       1   4 Jan 2015 22:43:35.931    4 Jan 2015 23:13:37.734          1801.803
                       2   5 Jan 2015 03:48:07.570    5 Jan 2015 04:19:55.061          1907.491

Global Statistics
-----------------
Min Duration           1   4 Jan 2015 22:43:35.931    4 Jan 2015 23:13:37.734          1801.803
Max Duration           2   5 Jan 2015 03:48:07.570    5 Jan 2015 04:19:55.061          1907.491
Mean Duration                                                                          1854.647
Total Duration                                                                         3709.294


CP140_Aurora-To-Cargo_Vessel_10
-------------------------------
                  Access      Start Time (UTCG)          Stop Time (UTCG)        Duration (sec)
                  ------   ------------------------   ------------------------   --------------
                       1   5 Jan 2015 07:26:04.337    5 Jan 2015 07:44:04.212          1079.875
                       2   9 Jan 2015 18:56:07.817    9 Jan 2015 19:08:30.190           742.373

Global Statistics
-----------------
Min Duration           2   9 Jan 2015 18:56:07.817    9 Jan 2015 19:08:30.190           742.373
```

Max Duration	1	5 Jan 2015 07:26:04.337	5 Jan 2015 07:44:04.212	1079.875
Mean Duration				911.124
Total Duration				1822.248

CP140_Aurora-To-Cargo_Vessel_2

Access	Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
1	5 Jan 2015 07:40:18.578	5 Jan 2015 07:41:04.995	46.417
2	9 Jan 2015 18:49:03.480	9 Jan 2015 19:07:28.998	1105.517

Global Statistics

Min Duration	1	5 Jan 2015 07:40:18.578	5 Jan 2015 07:41:04.995	46.417
Max Duration	2	9 Jan 2015 18:49:03.480	9 Jan 2015 19:07:28.998	1105.517
Mean Duration				575.967
Total Duration				1151.934

CP140_Aurora-To-Cargo_Vessel_3

No Access Found

CP140_Aurora-To-Cargo_Vessel_4

No Access Found

CP140_Aurora-To-Cargo_Vessel_5

Access	Start Time (UTCG)	Stop Time (UTCG)	Duration (sec)
1	4 Jan 2015 22:44:53.704	4 Jan 2015 23:16:03.089	1869.385
2	5 Jan 2015 03:46:34.478	5 Jan 2015 04:19:06.498	1952.020
3	9 Jan 2015 10:12:56.835	9 Jan 2015 10:23:33.511	636.676

```
                    4     9 Jan 2015 18:23:59.116     9 Jan 2015 18:55:11.451           1872.335
                    5     9 Jan 2015 19:07:29.000     9 Jan 2015 19:09:49.698            140.698

Global Statistics
-----------------
Min Duration        5     9 Jan 2015 19:07:29.000     9 Jan 2015 19:09:49.698            140.698
Max Duration        2     5 Jan 2015 03:46:34.478     5 Jan 2015 04:19:06.498           1952.020
Mean Duration                                                                           1294.223
Total Duration                                                                          6471.114


CP140_Aurora-To-Cargo_Vessel_6
------------------------------
                 Access       Start Time (UTCG)           Stop Time (UTCG)        Duration (sec)
                 ------    ------------------------    ------------------------    --------------
                      1    5 Jan 2015 07:21:20.592     5 Jan 2015 07:41:04.997           1184.405
                      2    9 Jan 2015 18:51:05.778     9 Jan 2015 19:10:28.209           1162.431

Global Statistics
-----------------
Min Duration        2     9 Jan 2015 18:51:05.778     9 Jan 2015 19:10:28.209           1162.431
Max Duration        1     5 Jan 2015 07:21:20.592     5 Jan 2015 07:41:04.997           1184.405
Mean Duration                                                                           1173.418
Total Duration                                                                          2346.836


CP140_Aurora-To-Cargo_Vessel_7
------------------------------
No Access Found


CP140_Aurora-To-Cargo_Vessel_8
------------------------------
                 Access       Start Time (UTCG)           Stop Time (UTCG)        Duration (sec)
                 ------    ------------------------    ------------------------    --------------
                      1    5 Jan 2015 07:26:04.337     5 Jan 2015 07:44:04.209           1079.871
```

```
Global Statistics
-----------------
Min Duration          1    5 Jan 2015 07:26:04.337    5 Jan 2015 07:44:04.209          1079.871
Max Duration          1    5 Jan 2015 07:26:04.337    5 Jan 2015 07:44:04.209          1079.871
Mean Duration                                                                          1079.871
Total Duration                                                                         1079.871


CP140_Aurora-To-Cargo_Vessel_9
------------------------------
                  Access      Start Time (UTCG)          Stop Time (UTCG)        Duration (sec)
                  ------   ------------------------   ------------------------   --------------
                       1   5 Jan 2015 07:40:18.578    5 Jan 2015 07:41:04.995            46.417

Global Statistics
-----------------
Min Duration          1    5 Jan 2015 07:40:18.578    5 Jan 2015 07:41:04.995            46.417
Max Duration          1    5 Jan 2015 07:40:18.578    5 Jan 2015 07:41:04.995            46.417
Mean Duration                                                                            46.417
Total Duration                                                                           46.417
```

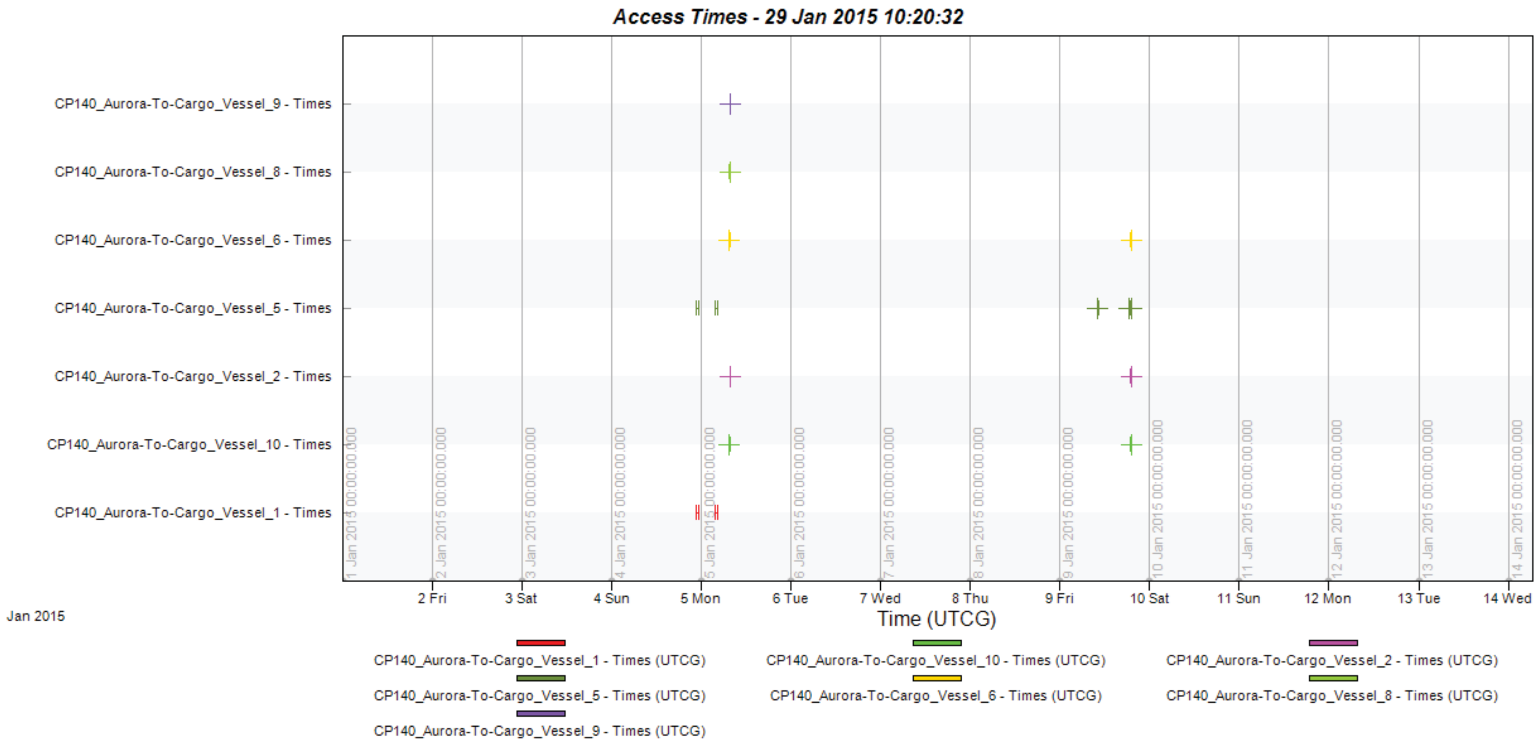


Figure D-7: Sample CP140 Access with Basic Constraints

APPENDIX E ACRONYMS AND ABBREVIATIONS

Acronym	Definition
AGI	Analytical Graphics Inc.
AIS	Automatic Information System
AOR	Area of Responsibility
CFB	Canadian Forces Base
CORA	Centre for Operational Research and Analysis
DEM	Digital Elevation Maps
DRDC	Defence Research and Development Canada
DTED	Digital Terrain Elevation Data
EO	Electro-Optic
GPS	Global Positioning System
GT	Gross Tonnage
IR	Infrared
ISR	Intelligence Surveillance and Reconnaissance
MARPAC	Maritime Command Pacific
RCN	Royal Canadian Navy
RCS	Radar Cross Section
RF	Radio Frequency
RS2	RadarSat2
SAR	Synthetic Aperture Radar
SDL	Space Dynamics Library
SOW	Statement of Work
SSC	Space Surveillance Catalogue
STK	System Toolkit
TA	Technical Authority

APPENDIX F REFERENCES

[1] http://www.forces.gc.ca/assets/FORCES_Internet/docs/en/operations/OP-LIMPID-bil.pdf accessed on 19 January 2015

[2] Obtained from http://www.forces.gc.ca/assets/FORCES_Internet/images/ops-maps-carte/sealion.jpg accessed on 21 January 2015

[3] Obtained from http://www.agi.com/resources/downloads/data/3d-models/Display.aspx?i=3056 accessed on 19 January 2015

[4] Obtained from http://upload.wikimedia.org/wikipedia/commons/3/39/Shipping_routes_red_black.png accessed on 22 January 2015

[5] Obtained from http://www.agi.com/resources/downloads/data/3d-models/Display.aspx?i=2385 accessed on 19 January 2015

[6] Obtained from http://www.agi.com/resources/downloads/data/3d-models/Display.aspx?i=1294 accessed on 19 January 2015

[7] Obtained from http://www.agi.com/resources/downloads/data/3d-models/Display.aspx?i=1549 accessed on 19 January 2015

[8] www.exactearth.com

[9] Obtained from http://airforceapp.forces.gc.ca/CFAWC/eLibrary/Journal/2012-Vol1/Iss1-Winter/Sections/12-Maritime_Air_e.pdf accessed on 26 January 2015

[10] Obtained from http://en.wikipedia.org/wiki/Beechcraft_Super_King_Air accessed on 25 January 2015

[11] Obtained from http://en.wikipedia.org/wiki/Beechcraft_Super_King_Air accessed on 25 January 2015

[12] Obtained from http://www.agi.com/resources/downloads/data/3d-models/Display.aspx?i=15007 accessed on 19 January 2015

[13] Obtained from http://www.dfo-mpo.gc.ca/international/media/bk_air-surveillance-aerien-eng.htm accessed on 20 January 2015

[14] Obtained from http://www.agi.com/resources/downloads/data/3d-models/Display.aspx?i=3165 accessed on 19 January 2015

[15] Obtained from http://www.hazegray.org/navhist/canada/systems/radar/ accessed on 20 January 2015

[16] Obtained from http://jproc.ca/rrp/halifax.html accessed on 20 January 2015

[17] A simple visual horizon formula that ignores atmospheric refraction is 1.23 x SQRT(height in feet) to give range in nautical miles (NM). For the IR and visual sensors, a nominal height of 25 feet was used giving 6.15 NM or approximately 10 km

[18] Obtained from http://www.agi.com/resources/downloads/data/3d-models/Display.aspx?i=3127 accessed on 19 January 2015

[19] Obtained from http://jproc.ca/rrp/kingston.html accessed on 20 January 2015

[20] Obtained from http://jproc.ca/rrp/kingston_radar.html accessed on 20 January 2015

[21] Obtained from http://www.naval-technology.com/projects/kingston/ accessed on 20 January 2015

[22] Obtained from http://www.forces.gc.ca/assets/FORCES_Internet/images/ops-maps-carte/sealion.jpg accessed on 21 January 2015

[23] Obtained from http://en.wikipedia.org/wiki/List_of_ports_and_harbors_of_the_Pacific_Ocean accessed on 17 January 2015

[24] Email forwarded from CAE to Dr. Peter Dobias, DRDC CORA on 9 February 2015, originating from AGI Technical Support

[25] Obtained from http://help.agi.com/stk/index.html?page=source%2Fextfile%2Finstall%2Fsysreq.htm accessed on 28 January 2015